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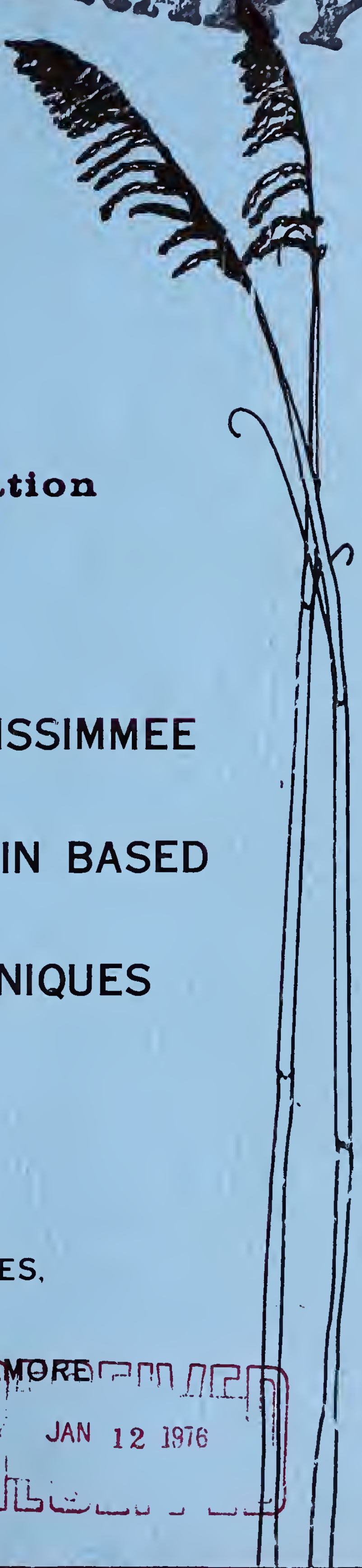

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LIMITING NUTRIENTS IN THE KISSIMMEE RIVER-LAKE OKEECHOBEE BASIN BASED ON ALGAL BIOASSAY TECHNIQUES

CRAIG W. DYE, DOUGLAS A. JONES,

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LIMITING NUTRIENTS IN THE KISSIMMEE RIVER-LAKE OKEECHOBEE BASIN BASED ON ALGAL BIOASSAY TECHNIQUES

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Abstract

Algal assays were conducted on water samples taken from 30 sites in the Kissimmee River-Lake Okeechobee Basin between October 1974 and February 1975. Results of these assays indicate that at the time of sampling, phosphorus was the limiting nutrient at a majority of sampling sites. Exceptions were noted at Shingle Creek and Lake Tohopekaliga where nitrogen was limiting. This may reflect the influence of the Orlando sewage treatment plants that pump their effluent into Shingle Creek. Results of the algal assays suggest that the trophic condition of Lake Okeechobee may be more a function of agricultural sources around the lake rather than Orlando domestic waste effluent.

Assays from Lake Okeechobee and several outflow canals exhibited a form of growth inhibition. Results of these assays suggest the presence of a metabolic inhibitor.

Introduction

There has long been a need for a critical analysis of the nutrients limiting to plant growth in the aquatic environment (Skulberg, 1966) and for many years responses of algal cultures to various nutrients have provided information on many aspects of algal growth (Tunzi, 1972). Only recently, however, have these bioassays been used to examine the causes of algal blooms; an important facet of eutrophication (Tunzi, 1972; Maloney, 1971; Maloney _et al_. 1972; Fitzgerald, 1972).

The algal bioassay is based on Leibig's Law of the Minimum which considers that plant growth is limited by the nutrient which is available in the smallest quantity relative to the needs of the organism (Odum, 1959). The application of this principle in artificial enrichment experiments using sterilized natural waters and selected algal species under carefully controlled laboratory conditions is the essence of the algal assay technique. This type of information is obviously very useful in the evaluation of water quality and in the planning of pollution control measures.

A full discussion of the concept of limiting nutrients is beyond the scope of this investigation. However, numerous researchers (e.g., Edmondson, 1972; 1974; Rodhe, 1969; Maloney _et al_., 1972; Miller _et al_., 1974) have found that, with few exceptions, the availability of nitrogen and/or phosphorus controls algal growth. Phosphorus particularly has often been cited as a limiting nutrient. This is not surprising since phosphorus is normally present in very low concentrations in nature (Golterman, 1973).

Other substances such as trace elements (Goldman, 1965) and chelators (Wetzel, 1965a) may also be important in regulating algal populations. Previous chemical investigations indicate, however, that nitrogen and/or phosphorus may be limiting in the Kissimmee-Okeechobee Basin. Therefore, this study was directed toward discovering which of these nutrients (or both) could be considered limiting in the basin.

Methods and Materials

The algal assay bottle test used in this study has become a standard method of determining algal growth-limiting nutrients (Maloney 1971; Weiss and Helms, 1971; Torien *et al.*, 1971). Additionally the test may be designed to identify the growth-limiting concentrations of the nutrients in question.

Beginning in October, 1974, algal assays were performed on water samples taken from 30 sampling sites in the Kissimmee River-Lake Okeechobee Basin (Figure 1). Due to time restrictions and the length of each assay (21 days), the majority of the effort was concentrated in the Lake Okeechobee area. Consequently, only one set of assays was conducted in the upper chain of lakes and the Kissimmee River.

It should be noted that seasonal changes in limiting nutrients can occur (*cf.*, Rodhe, 1969; Maloney, 1971; Smayda, 1974). For this reason, the present study may not be entirely applicable to the full seasonal cycle. Despite this limitation, certain trends of nutrient limitations are readily apparent.

Sampling dates are indicated in Table 1, along with a summary of probable limiting nutrients. Each sample consisted of a composite of water samples taken at surface, mid-depth, bottom and Secchi disc depth. All samples were collected with a 2 liter modified PVC van Dorn water sampler. The composite sample was transferred to a previously autoclaved polycarbonate container, which was kept on ice at 4°C in the dark until prepared for the assay.

Preparation of the water sample consisted of autoclaving for 30 minutes at 15 p.s.i. above atmospheric and 260°C followed by filtration through a 0.45 micron membrane filter. Sixty ml aliquots of the filtered sample were then transferred to 250 ml Erlenmeyer flasks for the bottle assay. Nutrient spikes were added to the flasks at this time. Triplicate flasks of each control and each nutrient spiked sample were prepared and injected with 1000 cells per ml of the test algal species (*Selenastrum capricornutum*).

A nitrogen-phosphorus ratio of 10:1 was selected for the nutrient spikes. Previous data from the Kissimmee-Okeechobee Basin indicated that this ratio was typical of the surface waters. Rather high nutrient concentrations of the spikes were used to ensure a growth response since the exact concentration of nutrients at each sampling point was not known. Nutrient spikes, with the exception of some Lake Okeechobee experiments were of the following concentrations:

Nitrogen (N)	Phosphorus (P)
0.5 mg/1	0.05 mg/1
1.5 mg/1	0.15 mg/1
4.5 mg/1	0.45 mg/1

Nitrogen (N) + Phosphorus (P)
0.5 mg/1 + 0.05 mg/1
1.5 mg/1 + 0.15 mg/1
4.5 mg/1 + 0.45 mg/1

The samples were cultured under constant lighting of six (6) 40-watt G.E. "Cool White" fluorescent bulbs to give an illumination of 400 foot-candles at the liquid level of the flasks while being mechanically shaken at 100 oscillations per minute. Temperature of the culture room was maintained at 22 ± 2°C.

Stock cultures of Selenastrum capricornutum Printz were obtained from the EPA, Corvallis, Oregon. These cultures were grown in artificial media (PAAP media, Pacific Northwest Environmental Research Laboratory) for use as innocula for the algal assay. This media was prepared as outlined in Maloney (1971).

Cell counts, to determine growth response, were made on days 1 through 7 and also on days 10, 13, 17 and 21 of an experiment. Algal cells in 1 ml aliquots from each flask were counted on an electronic particle counter (Coulter Model ZBI) with mean cell volume attachment.

Results and Discussion

Table 1 summarizes the results of limiting nutrient algal assays in the Kissimmee-Okeechobee Basin between 2 October 1974 and 25 February 1975. These results indicate that, when sampled, algal growth in the basin was generally limited by phosphorus, or a combination of nitrogen and phosphorus. There were, however, notable exceptions at Shingle Creek, Lake Tohopekaliga, Taylor Creek, and perhaps Nubbin Slough, all of which appeared to be nitrogen limited at the time of sampling. Moreover, an unexpected pattern of algal growth response was discovered in Lake Okeechobee itself.

Assays on waters from East Lake Tohopekaliga (Figures 2, 3, and 4) indicated that at the time of sampling, the lake was probably phosphorus limited. The lowest test concentration of phosphorus (0.05 mg/1) seemed to be the threshold concentration for greatest growth, and higher concentrations of phosphorus, and combined nitrogen and phosphorus additions did not have any significant stimulatory effect on the cultures.

Samples from Shingle Creek (Figures 5, 6, and 7) and Lake Tohopekaliga (Figures 8, 9, and 10) demonstrated that both water bodies were nitrogen limited when sampled. Nitrogen concentrations of 1.5 mg/1 and 0.5 mg/1 stimulated maximum growth responses in Shingle Creek and Lake Tohopekaliga, respectively. Shingle Creek is the receiving body of water for the two largest sewage treatment plants in the entire study area, and receives totals of 1,481,000 pounds per year of nitrogen and 29,567 pounds per year of phosphorus from these sources alone. Burton et al. (1975) and Federico and Brezonik (1975) have demonstrated that Shingle Creek is not able to assimilate these levels of sewage effluent loadings. In addition, Federico and Brezonik (1975) have computed a nutrient budget for Lake Tohopekaliga, which indicates that Shingle Creek supplies 31% of the nitrogen and 40% of the phosphorus load to the Lake annually. An additional 203,000 pounds per year of nitrogen and 120,000 pounds per year of phosphorus are fed directly or indirectly to the Lake from other surface discharging sewage treatment plants. It should also be noted that Shapiro (1975) has shown that Lake Tohopekaliga is currently acting as a phosphorus sink as an accidental result of the water management scheme currently in effect. The present nitrogen limitations of Shingle Creek and Lake Tohopekaliga are almost certainly related to the magnitude of phosphorus loading from point sources.

Results of control assays on samples from Lake Tohopekaliga indicate that, at the time of sampling, the lake was capable of supporting a large algal growth.

Results of analyses from Lake Cypress (Figures 11, 12, and 13) appeared to indicate that the lake was phosphorus limited when sampled. A combination of the highest concentrations of nitrogen and phosphorus seemed to stimulate algal growth only slightly more than phosphorus alone (Figure 13). The results of the control assays suggest that at the time of sampling the natural waters of Lake Cypress may have been able to stimulate a moderate growth of phytoplankton.

Lake Hatchineha (Figures 14, 15, and 16) exhibited a situation, when sampled, in which phosphorus appeared to be limiting at a threshold value of 0.05 mg/l, but moderate and high concentrations of nitrogen and phosphorus in combination significantly stimulated growth. This observation suggests that there may be some positive synergistic effect between nitrogen and phosphorus, since nitrogen alone appeared to inhibit growth. This apparent nitrogen inhibition appeared in several samples during the course of this study. No explanation for the effect is available.

Analyses of samples from Lake Kissimmee (Figures 17, 18, and 19) demonstrated that a threshold concentration of 0.05 mg/l of phosphorus stimulated growth, indicating probable phosphorus limitation at the time of sampling. Nitrogen and phosphorus combinations were slightly more stimulating at higher concentrations. An unexplained decrease in growth in the phosphorus spiked cultures after seven days paralleled a drop in the control cultures (Figure 17). The experimental cultures receiving higher concentrations in the phosphorus spikes (Figures 18 and 19) did not show the inhibition effect seen in the controls and low phosphorus tests.

The Kissimmee River (C-38) was sampled at four locations. Results of the assays at Station G (an oxbow or portion of the old river channel) suggest that phosphorus was the limiting nutrient on the sampling date at a threshold concentration of 0.05 mg/l (Figures 20, 21, and 22). It should be noted that the highest concentrations of nitrogen and phosphorus in combination appeared to stimulate algal growth at this station, although nitrogen alone did not (Figure 22). Station H (the present channel of the canal opposite Station G) was very similar to Station G in that phosphorus also appeared to be limiting at a threshold concentration of 0.05 mg/l (Figures 23, 24 and 25). The medium and highest concentrations of nitrogen and phosphorus in combination were more stimulatory than phosphorus alone (Figures 24 and 25). Nitrogen alone did not cause an increase in growth and, in fact, appeared to inhibit growth at this station (Figure 24). At station Ia (the present channel of the canal near S-65D), phosphorus continued to appear to be limiting at the time of sampling (Figures 26, 27, and 28). A concentration of phosphorus of 0.05 mg/l produced the largest growth for a single nutrient spike. Combinations of nitrogen and phosphorus stimulated algal growth only slightly above that of phosphorus alone. Additionally, the control waters from this station appeared capable of supporting a large population of algae. Samples from the fourth station (Station N, at the mouth of the river) also seemed to indicate phosphorus limitation (Figures 29, 30, and 31). A threshold phosphorus concentration of 0.05 mg/l stimulated the greatest amount of growth of the single nutrient spikes. Combination nitrogen and phosphorus spikes were slightly more growth-stimulating than phosphorus alone, suggesting that phosphorus was initially limiting, but when sufficient quantities of phosphorus were available, nitrogen became limiting. Also, at the time of sampling, the natural waters at this station appeared capable of supporting a moderate growth of algae.

Assays of a sample from Nubbin Slough indicated that all single and mixed nutrient spikes had similar stimulatory effects (Figures 32, 33, and 34), although nitrogen alone spurred growth slightly over phosphorus alone and about the same degree as nitrogen-phosphorus combinations. These results suggest that, when sampled, Nubbin Slough bordered on being nitrogen limited. Control samples indicated that the slough was capable of supporting a large algal population.

Analyses of samples from Taylor Creek indicated that that system was also probably nitrogen limited when sampled (Figures 35, 36 and 37). Nitrogen spikes at a concentration of 0.5 mg/l stimulated significant algal growth, as did the higher concentrations of nitrogen and phosphorus in combination (Figure 37). Additionally, the natural water of Taylor Creek was capable of stimulating moderate algal growths when sampled.

Results obtained from analyses of Indian Prairie Creek (Figure 38) indicated that neither nitrogen nor phosphorus significantly stimulated growth in comparison with the control, although nitrogen plus phosphorus did cause a significant increase in growth. The growth curves presented in Figure 38 suggest that phosphorus was slightly limiting at the time of sampling. The natural waters of this station appeared capable of supporting a fairly large amount of algal growth at the time of sample collection.

Results of assays on samples from Harney Pond Canal are shown in Figure 39. The nitrogen spike produced a significant increase in algal growth while the nitrogen plus phosphorus spike stimulated the production of even greater growth. These data suggest that, at the time of sampling, nitrogen was initially limiting, but in the presence of sufficient concentrations of nitrogen, phosphorus became limiting. The natural water at this station also appeared capable of supporting a moderate growth of phytoplankton.

Fisheating Creek, at the time of sampling appeared to be phosphorus limited initially (Figure 40). However, the data seem to indicate that with sufficient concentrations of phosphorus, nitrogen became limiting. The results of the control assay suggest that the natural waters of Station Z were capable of supporting moderate growths of algae at the time of sampling.

The remaining assays were performed on samples from Lake Okeechobee and its effluent streams. The first set of samples, taken in November, 1975, from two stations in Lake Okeechobee (Stations L and M) exhibited unusual growth patterns that suggested a possible nutrient-trace element deficiency or algal inhibitor. The growth alterations consisted of a significant growth lag of approximately 7-10 days and a generally flattened growth curve (Figures 41, 42, 43, 44, 45, and 46). This response contrasts markedly with growth responses of water samples from the Chain of Lakes and the Kissimmee River (compare Figures 30 and 45).

Nevertheless, at these two stations, phosphorus spikes stimulated growth of the algal cultures, suggesting that the November samples were phosphorus limited (e.g., Figures 42 and 45). A phosphorus concentration of 0.05 mg/l seemed to be the threshold value. Combination nitrogen and phosphorus spikes caused only slightly more growth (Figures 42 and 44).

Chemical data on Lake Okeechobee indicated that certain trace elements (boron, copper, manganese) were in short supply (Joyner, 1974). Joyner (1974) also suggested that the concentrations of these trace elements were below the minimum required for healthy algal growth. Lindahl and Melin (1973) and Goldman (1965) found trace elements limited algal growth in certain situations. Miller et al. (1974) and Gerloff and Skoog (1957) found that manganese and iron were important algal nutrients in hard water lakes and that manganese may even inhibit algal growth in certain instances.

Hypothesizing that trace elements may have limited algal growth in Lake Okeechobee, additional samples were taken in January, 1975, and spiked with artificial media (PAAP) trace elements. The trace element spike consisted of the following concentrations of elements.

Boron	32.46 µg/L
Manganese	115.374 µg/L
Zinc	15.691 µg/L
Cobalt	0.354 µg/L
Copper	0.004 µg/L
Molybdenum	2.878 µg/L

In addition to a trace element spike, a trace element plus 4.5 mg/1 nitrogen and 0.45 mg/1 phosphorus combination spike was included. Twelve sampling locations were established on a north-south transect in Lake Okeechobee from the mouth of the Kissimmee River (Station N) to an area between Ritta Island and Kreamer Island near South Bay (Station M, Figure 1).

The results of the January assay at Station Q (Figure 47) are representative of results from the other stations in the lake. These data indicate that a trace element deficiency was probably not involved since no significant growth was observed in the cultures spiked with trace elements or trace elements plus nitrogen and phosphorus.

The only non-lake station of the January sampling, Station N, at the mouth of the Kissimmee River, exhibited somewhat "normal" growth responses (Figure 48). It is interesting to note that at Station N only the trace element plus nitrogen and phosphorus spike stimulated growth over that of the control. Also, of the single nutrient plus trace element spikes, the phosphorus spike stimulated growth slightly more than the nitrogen spike. The general nutrient limitation at this station (i.e., phosphorus limited) generally remained much the same for the January assay as for the December assay (compare Figures 30 and 48).

Wetzel's (1965a, 1966) work on hard water lakes suggested the importance that chelating agents have in making nutrients available for algal growth in the presence of excessive cations. Jordan and Bender (1973) and Jordan (1973) also found that chelating substances stimulated algal growth in similar studies. Also, Schelske (1960) established that nutrient enrichment of algae showed negligible effects unless chelated iron was available.

Since the algal cultures from Lake Okeechobee samples were still not responding to trace elements, a chelator was tested as a possible growth stimulant. A mid-lake station (Station S) was selected which after 10 days, appeared to be following the abnormal growth pattern found in all the lake samples. Samples from Station S were injected with 1 ml of 0.3 mg/l concentration of Na_2 ethylenedinitrilo tetraacetic acid, a chelating agent, on day 10 of the assay.

The results of the chelation experiment are presented in Figure 49. The trace element plus nitrogen and phosphorus and control samples assumed a somewhat normal growth curve. Although growth was stimulated slightly, the trace element spike alone still seemed to be inhibited. These data suggested that lack of chelating substances may have been the growth inhibiting factor. Therefore, a chelator spike was included in certain assays from a third series of samples, taken from Lake Okeechobee and its effluent waters during February, 1975. In this series, outflows from Lake Okeechobee were sampled at the Caloosahatchee River (Station Ib), Miami Canal (Station II), West Palm Beach Canal (Station III), and St. Lucie Canal (Station IV), as well as Lake Okeechobee itself.

Assays from the Caloosahatchee River demonstrated that the nitrogen plus phosphorus spike produced the greatest algal growth while phosphorus alone was slightly stimulatory. The data in Figure 50 suggest that while phosphorus was initially limiting, with an adequate supply of phosphorus, nitrogen became limiting. Results of the control assay reveal that at the time of sample collection the natural waters of Station Ib would have supported a large phytoplankton population. This was found to be the only Lake Okeechobee effluent station in which the inhibitory effect was absent. It should be observed that this station is in the southwestern corner of the lake, fairly far removed from the remaining effluent stations in the southeastern portion of Lake Okeechobee.

Results of analyses from the Miami Canal seemed to show a perceptible growth lag of about 4 days (Figure 51) and a depressed growth curve. The phosphorus spike significantly stimulated algal growth cultures. Nitrogen and phosphorus spikes produced only a negligible increase in growth over that of phosphorus alone. This suggests that at the time of sample collection phosphorus may have been limiting. Also at the time of sample collection, the natural waters may have been able to support a moderate population of phytoplankton.

Samples taken from the West Palm Beach Canal showed a growth lag of approximately 6-7 days with a resultant flattening of the growth curve (Figure 52). Although the results from this assay are difficult to interpret, the phosphorus spike stimulated the greatest amount of growth. Therefore, at the time of sampling, phosphorus appeared to be the limiting nutrient. It is difficult to make conclusions concerning the ability of the natural waters at Station III to support algal growth. However, after the growth lag, a moderate phytoplankton population could have developed.

Assays on waters from the St. Lucie Canal indicated an extreme depression of the growth curve of 8-10 days (Figure 53) when compared to the condition in the lake (Figure 45). Phosphorus spikes stimulated the greatest amount of algal growth, suggesting that at the time of sampling phosphorus was likely the limiting nutrient. Assays of natural waters indicate that this station was incapable of supporting large algal populations. It should be noted that, although the unknown inhibiting substance produced a negative response in laboratory algal cultures, it may not be totally inhibiting to indigenous species.

The February assays of Lake Okeechobee were particularly designed to determine if pH or a lack of chelating substances was responsible for the inhibition observed in earlier assay and discussed previously (Figures 54, 55, and 56). Lake Okeechobee is considered to be a hard water, marl lake with a normal pH range of 7.8 - 9.0 and high bicarbonate alkalinity (Joyner, 1974). According to some authors (e.g., King, 1972; Kerr et al., 1972; Foree, 1972) at pH values such as those found in Lake Okeechobee, the lack of free CO_2 could limit the growth of algae.

To test this hypothesis the pH of Lake Okeechobee test water was adjusted from pH 8.45 to pH 7.2 (the average pH of Kissimmee River water) with 1% HCl. The results of this experiment are presented in Figures 54, and 55. The pH adjusted cultures did not grow significantly better than the control cultures even with the addition of nitrogen and phosphorus. Also the 7-day growth lag observed in earlier experiments was still evident. These data suggested that high pH may not be the factor controlling the growth of these algal cultures.

The possibility of growth inhibition related to chelation, noted above, was also further tested. The results of the February assay, indicate that the spikes with chelator did not stimulate and may even have inhibited algal growth. Also, the PAAP plus chelator spike seemed to inhibit growth (Figure 56) even though the PAAP media contains the required nutrients for normal algal growth.

These results suggest the possibility of interference by a metabolic inhibitor. Smayda (1974) has suggested that conditioning of the water-mass by phytoplankton growth, perhaps through organic or inorganic excretions, may influence growth patterns by altering chelation or trace metal properties. Extracellular inhibitory substances (probably long chain fatty acids) have been described from the green alga *Chlamydomonas* (Proctor, 1957a, and 1957b) and the blue-green alga *Aphanizomenon* (Lange, 1971). Additionally, van der Post and Toerien (1974) observed an unknown algal inhibitor excreted by algae in a sewage maturation pond. Boyd (1973) has suggested that macro-algae (*Chara* sp. in this case) excreted antibiotic substances which inhibited photoplankton-production in catfish ponds. Also, investigators at the University of Southern Mississippi have isolated inhibiting substances from *Chara foliolosa* and *Eleocharis microcarpa* that supress the growth of blue-green algae (Anon., 1974). The researchers at Southern Mississippi have demonstrated that the extra-cellular substances excreted by *Chara* and *Eleocharis* inhibit algal growth at concentrations as low as 1.0 mg/l.

There are large areas of Chara sp., Eleocharis sp. and other macrophytes in the littoral areas of the southern part of Lake Okeechobee (M. Marshall, F.C.D. biologist, personal communication). Also, the most pronounced algal inhibition occurs in the southern portions of the lake. Therefore, the possibility that substances excreted by littoral macrophytes may inhibit algal production in Lake Okeechobee may be correct.

Although inconclusive, the algal assays performed on samples from Lake Okeechobee suggest the presence of an algal inhibitor. Whether the inhibition observed was induced by a metabolic substance or by unusual chemical properties of the lake water can only be answered by further experimentation.

Conclusions

The results of algal assays performed in the Kissimmee-Okeechobee Basin suggest a relationship between annual nutrient loading rates and algal limiting nutrients. This is particularly clear in the cases of Shingle Creek and Lake Tohopekaliga in which nitrogen limitation is the obvious consequence of relatively very large phosphorus loadings. As previously stated, algal assays of both bodies of water indicated that they were nitrogen limited at the time of sample collection.

Other areas for which nutrient loading rates were available (i.e., Kissimmee River, backpumping areas of Lake Okeechobee, Taylor Creek, Nubbin Slough) have considerably higher nitrogen than phosphorus loadings. The assays performed at those sites indicated that they were, for the most part, phosphorus limited. The notable exception was Taylor Creek and perhaps Nubbin Slough, both of which appeared to be nitrogen limited on the date tested. The discrepancy between these results and the observed nitrogen loading rates for Taylor Creek - Nubbin Slough illustrates the need for assays to be conducted on a seasonal basis. Assay results for these stations were instantaneous measurements that may not have reflected the typical nutrient situation in a particular area. However, it seems likely that the algal assays have shown the general trend toward phosphorus limitation in the basin that appears to correlate with the observed nitrogen and phosphorus loading figures.

An objective of the assays was to determine the effect sewage treatment plants in the Orlando area might have on the Upper Chain of Lakes, the Kissimmee River and Lake Okeechobee. It is difficult to base unequivocal conclusions on the limited number of assays performed on the upper basin; but present results indicate that the effects of the domestic waste are mainly felt in Shingle Creek and Lake Tohopekaliga. This is not to say that in the future excessive nutrients from the Orlando area will not affect other lakes in the chain, the river, or Lake Okeechobee. There is no doubt that the Orlando area is having some effect on nutrient loadings in Lake Okeechobee, but the effect is probably minimal compared to other sources around the lake itself.

The inhibitory response observed in Lake Okeechobee presents an interesting problem with respect to limiting algal growth. However, it is difficult to judge the effect an algal inhibitor has had on the trophic condition of the lake. Only future experimentation will tell if the inhibition affects only the unialgal cultures used for this study or whether indigenous species of Lake Okeechobee are also affected.

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TABLE 1

Probable Limiting Nutrient for 30 Locations In the Kissimmee - Okeechobee Basin, 2 October 1974 - 5 February 1975

Station	Location	Date of Sampling	Probable Limiting Nutrient
A	East Lake Tohopekaliga	10/2/74	P
B	Shingle Creek	10/2/74	N
C	West Lake Tohopekaliga	10/2/74	N
D	Lake Cypress	10/2/74	P
E	Lake Hatchineha	10/2/74	P
F	Lake Kissimmee	10/30/74	P
G	Oxbow in C-38	10/30/74	P
H	C-38 opp. oxbow	10/30/74	P
I	C-38 near S65D	10/30/74	P
J	Nubbin Slough	11/27/74	N
K	Taylor Creek	11/27/74	N
L	Northern Lake Okeechobee	11/27/74	P
L	Northern Lake Okeechobee	1/07/75	?
M	Southern Lake Okeechobee	11/27/74	P
M	Southern Lake Okeechobee	1/07/75	P?
M	Southern Lake Okeechobee	2/05/75	P
N	Mouth of C-38	11/27/74	P
N	Mouth of C-38	1/07/74	P
O	Northern Lake Okeechobee	1/07/75	?
P	Northern Lake Okeechobee	1/07/75	?
Q	Center Lake Okeechobee	1/07/75	?
R	Center Lake Okeechobee	1/07/75	?
S	Center Lake Okeechobee	1/07/75	?
T	Center Lake Okeechobee	1/07/75	?
U	Southern Lake Okeechobee	1/07/75	?
V	Southern Lake Okeechobee	1/07/75	?
W	Southern Lake Okeechobee	1/07/75	?
X	Indian Prarie Canal	2/05/75	P
Y	Harney Pond Canal	2/05/75	N
Z	Fisheating Creek	2/05/75	P
Ib	Caloosahatchee River	2/05/75	P
II	Miami Canal	2/05/75	P
III	West Palm Beach Canal	2/05/75	P
IV	St. Lucie Canal	2/05/75	P

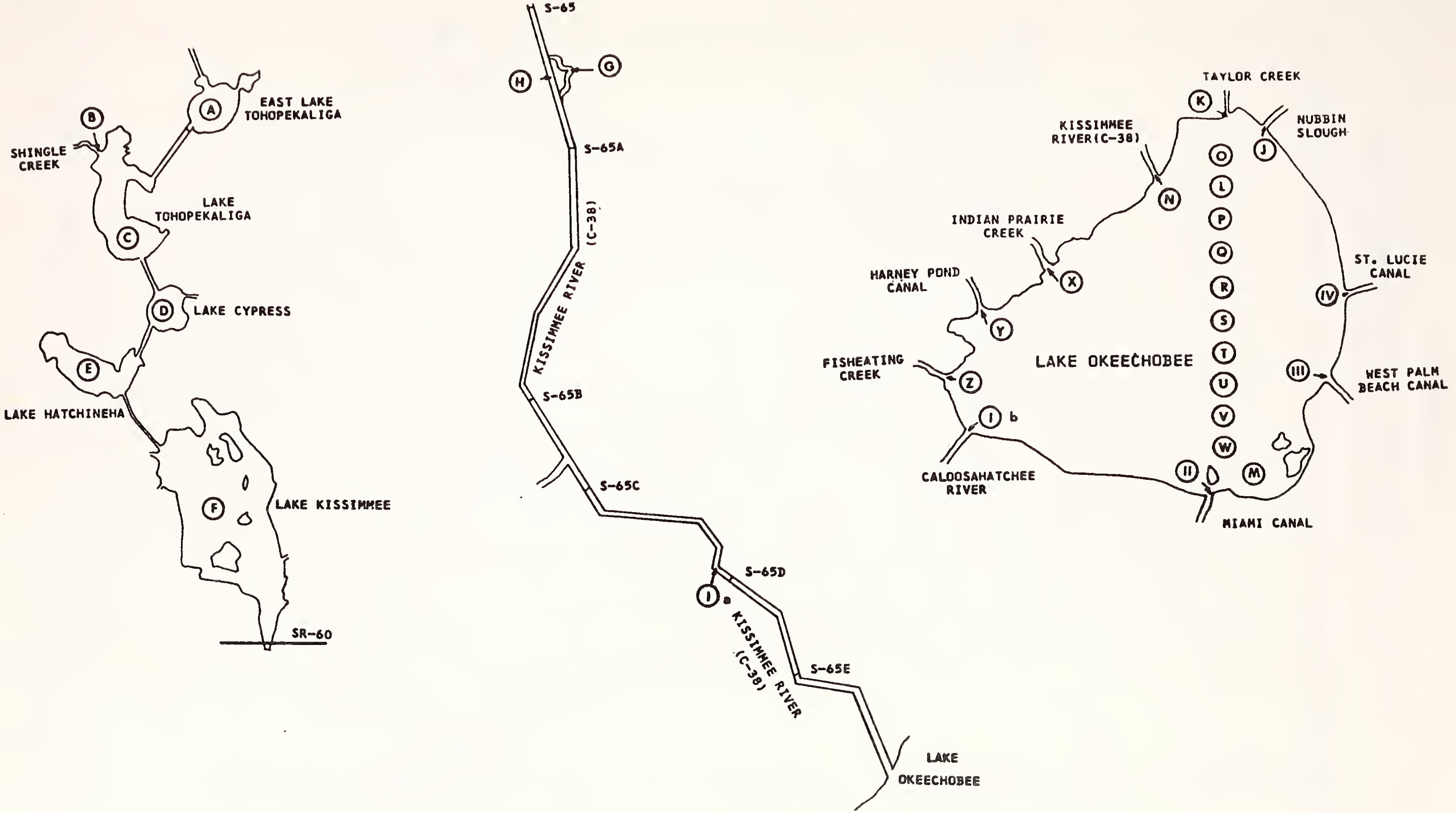


FIGURE 1

Map of Kissimee River-Lake Okeechobee Basin. Map shows location of 30 stations used for algal assays.

FIGURE 2

Effect of various nutrient additions to water from Station A on growth of *Selenastrum capricornutum*.

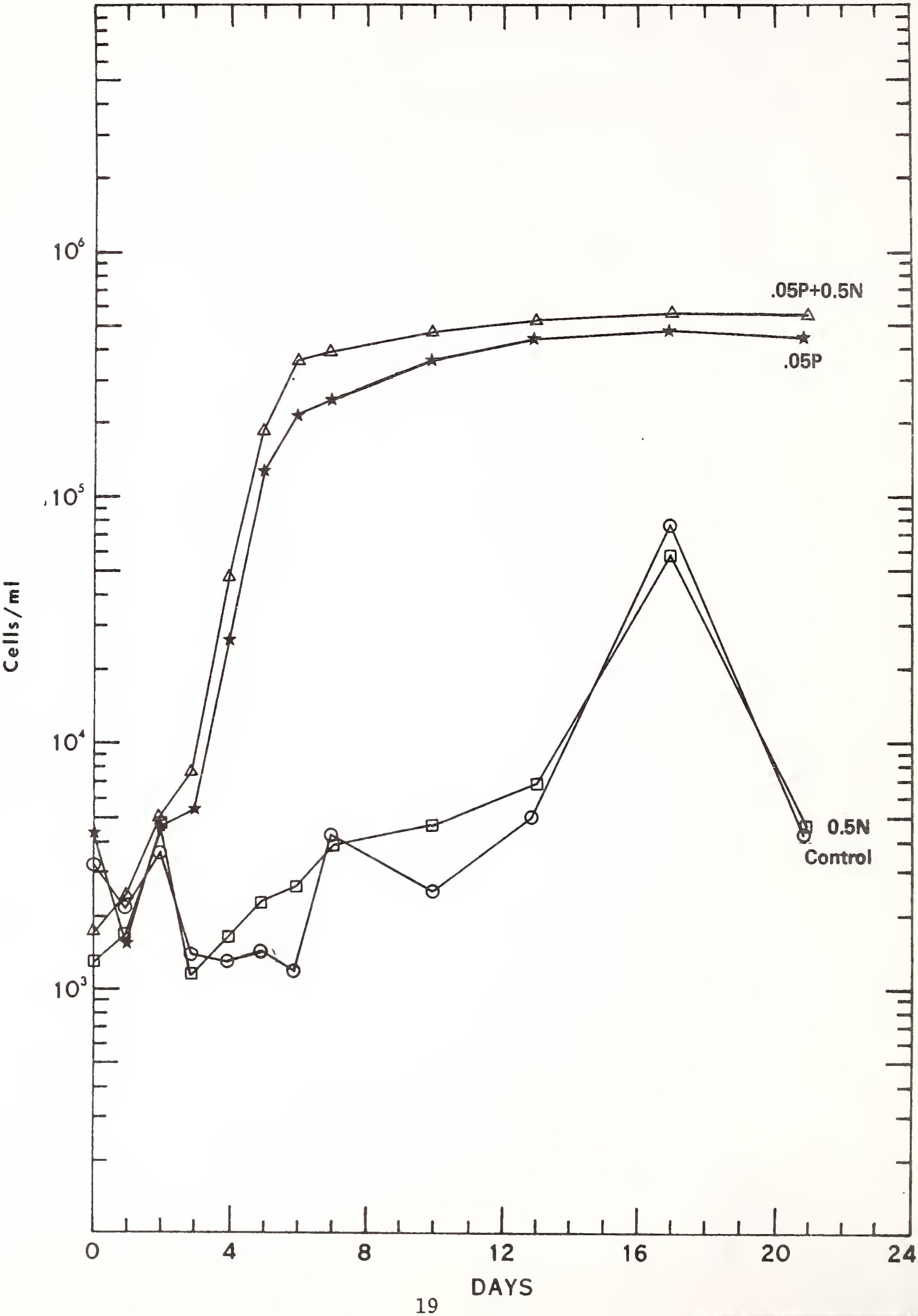


FIGURE 3

Effect of various nutrient additions to water from Station A on growth of *Selenastrum capricornutum*.

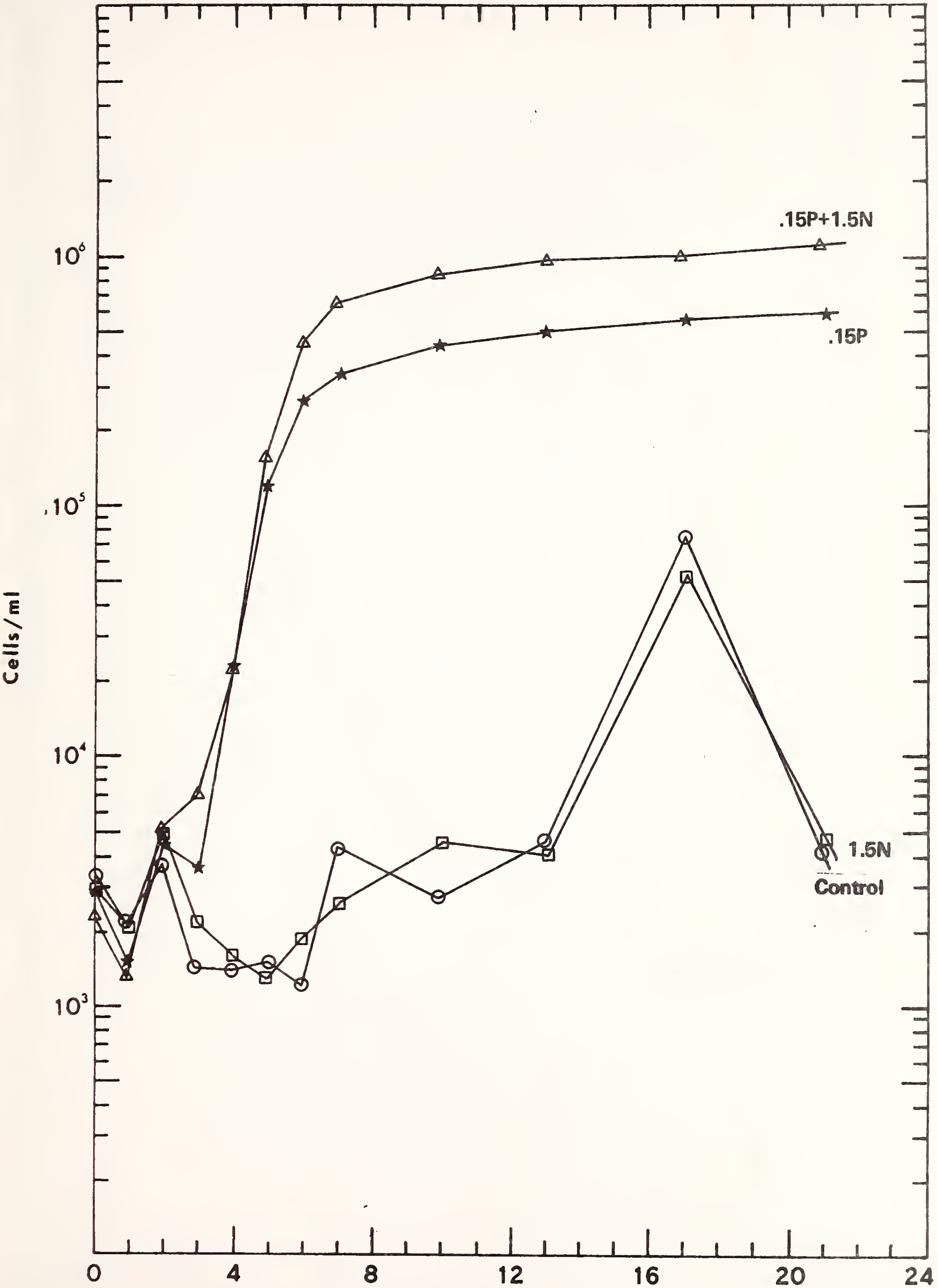


FIGURE 4

Effect of various nutrient additions to water from Station A on growth of *Selenastrum capricornutum.*

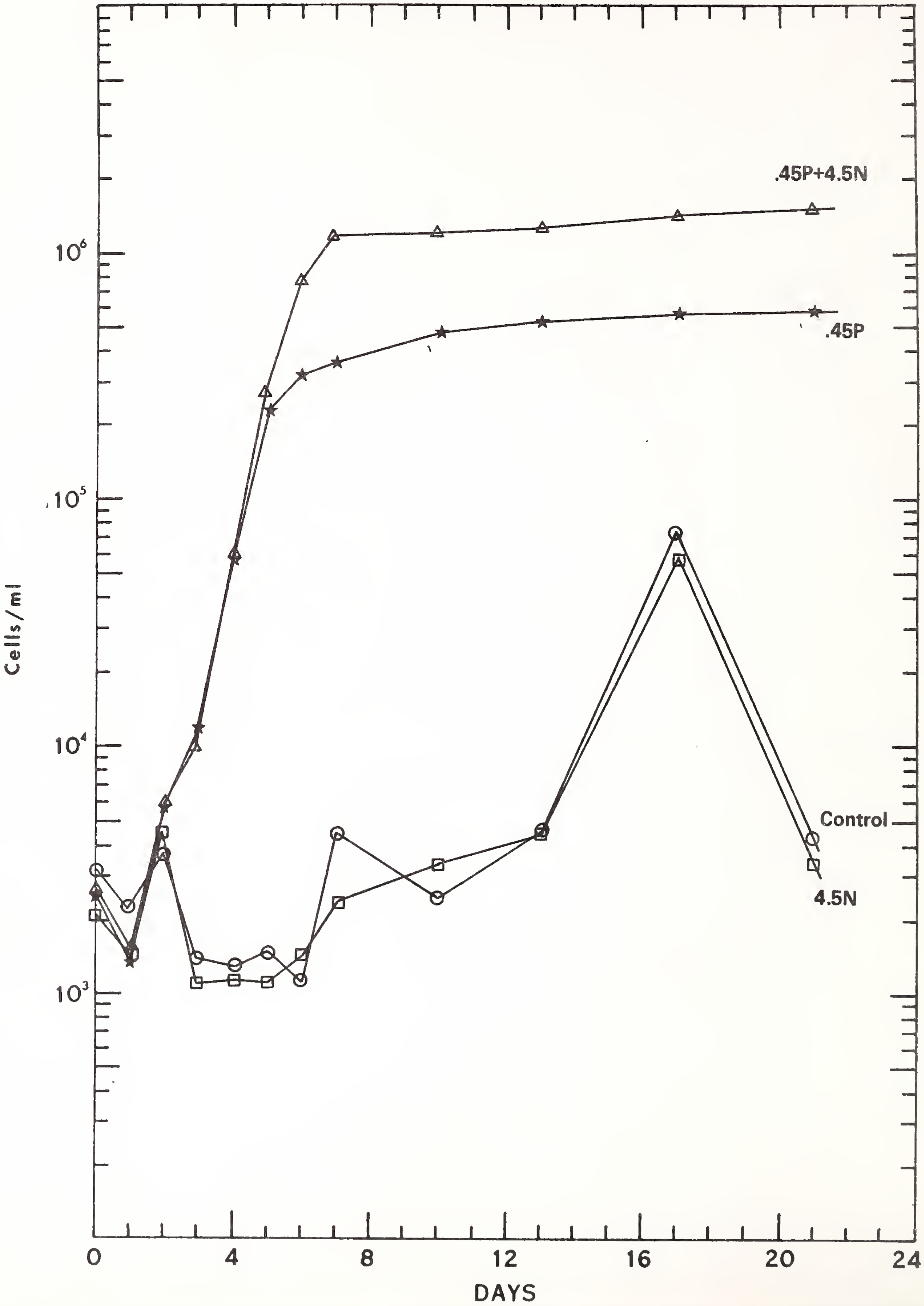


FIGURE 5

Effect of various nutrient additions to water from Station B on growth of *Selenastrum capricornutum.*

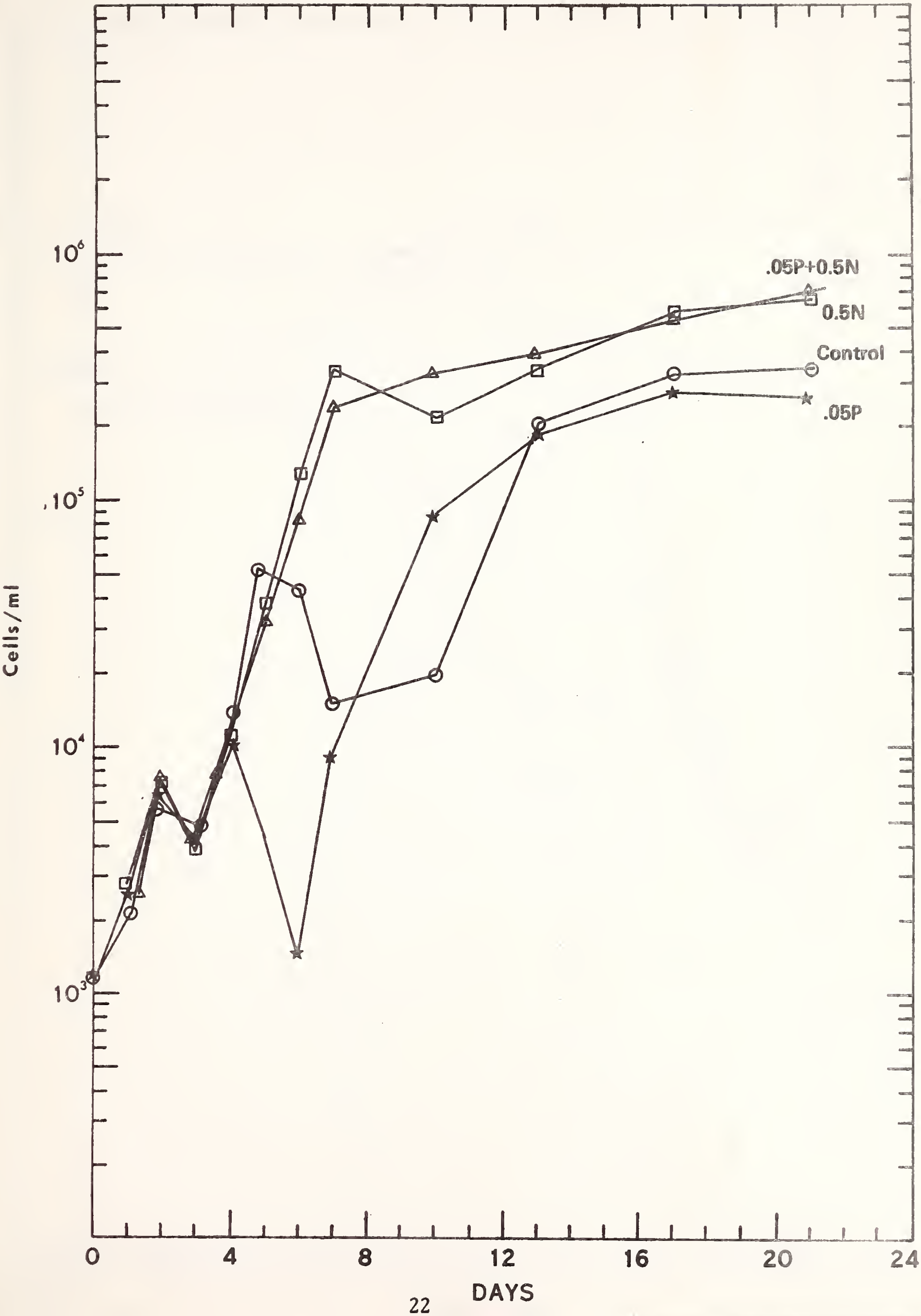


FIGURE 6

Effect of various nutrient additions to water from Station B on growth of *Selenastrum capricornutum.*

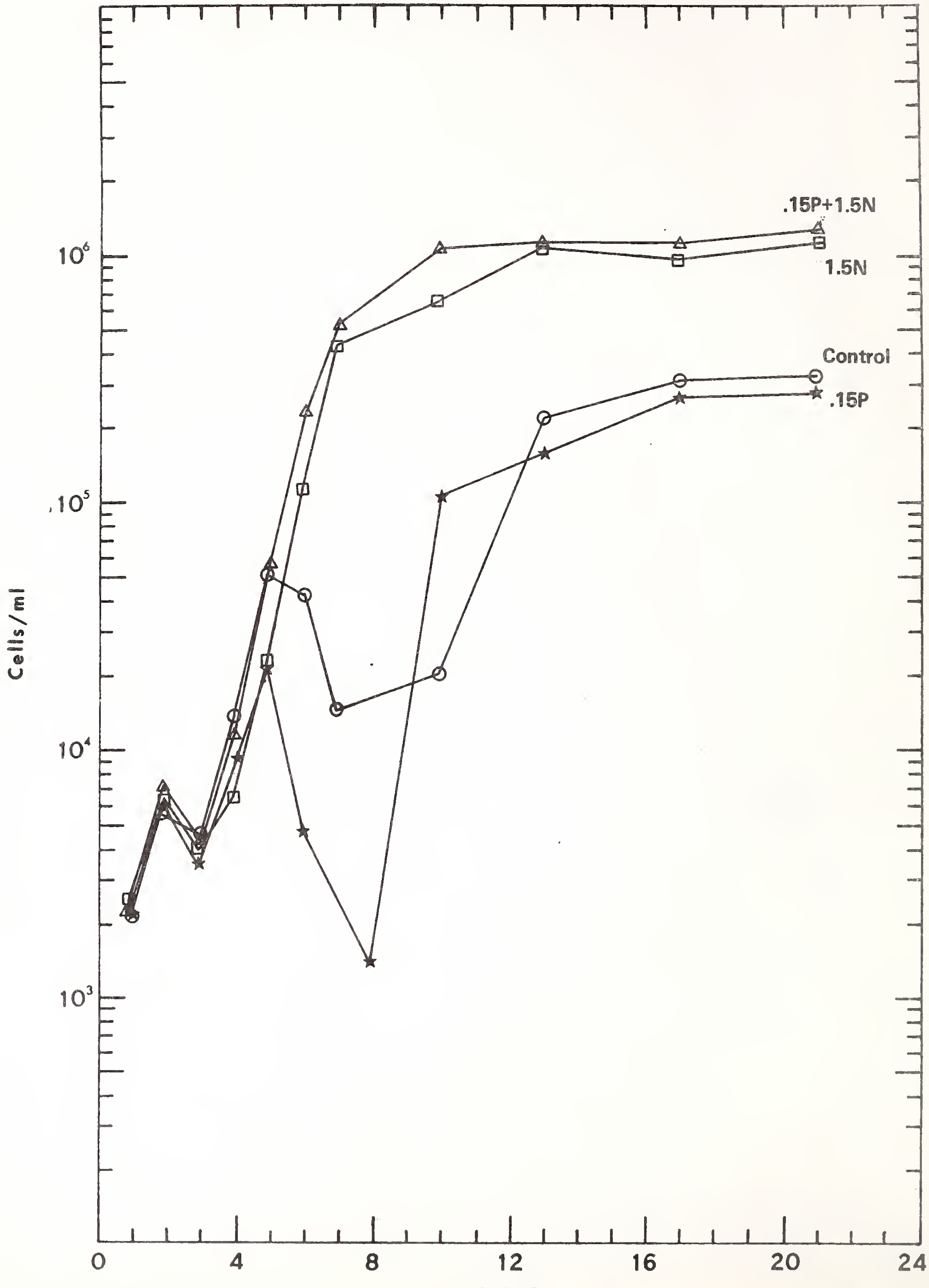


FIGURE 7

Effect of various nutrient additions to water from Station B on growth of *Selenastrum capricornutum*.

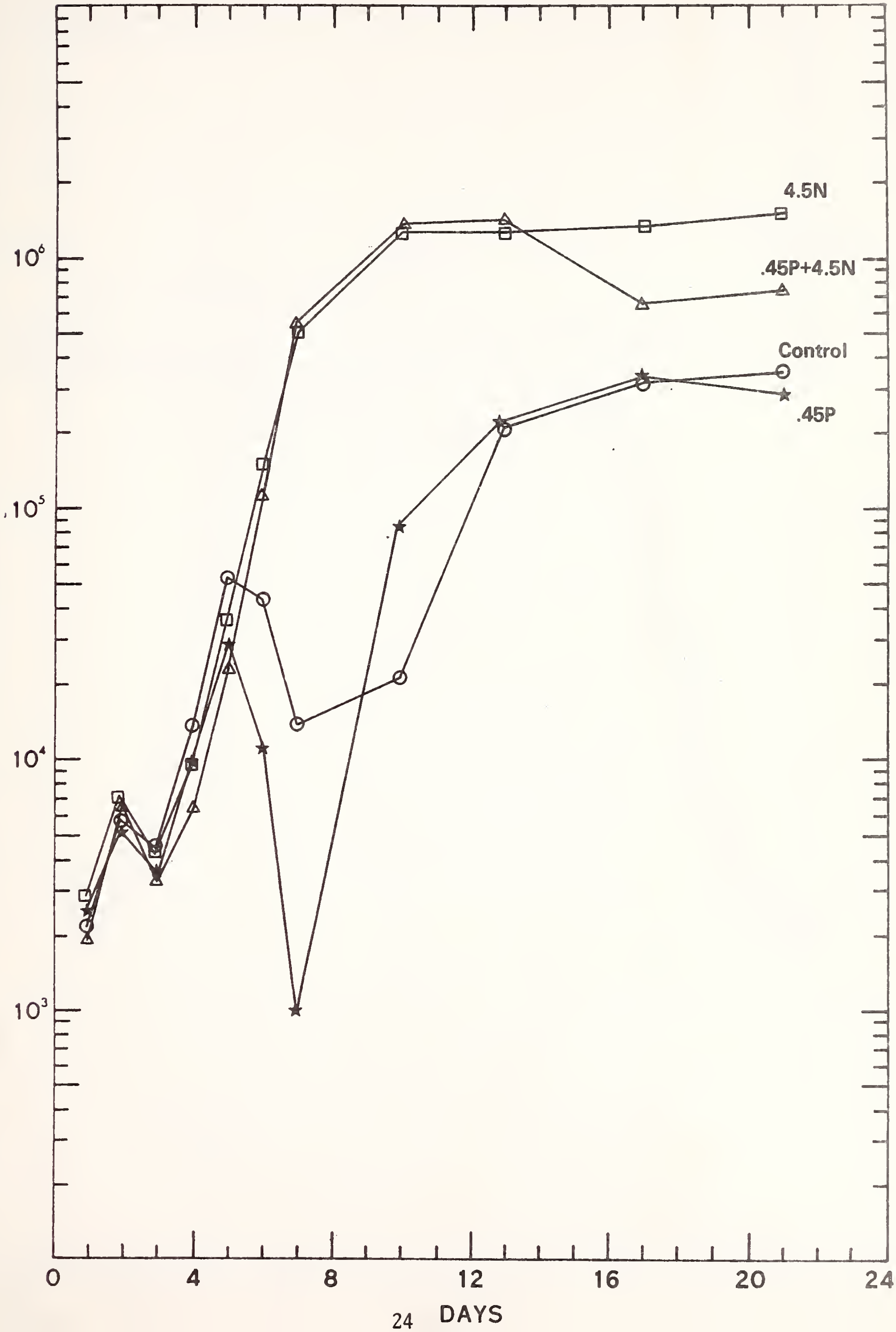


FIGURE 8

Effect of various nutrient additions to water from Station C on growth of *Selenastrum capricornutum.*

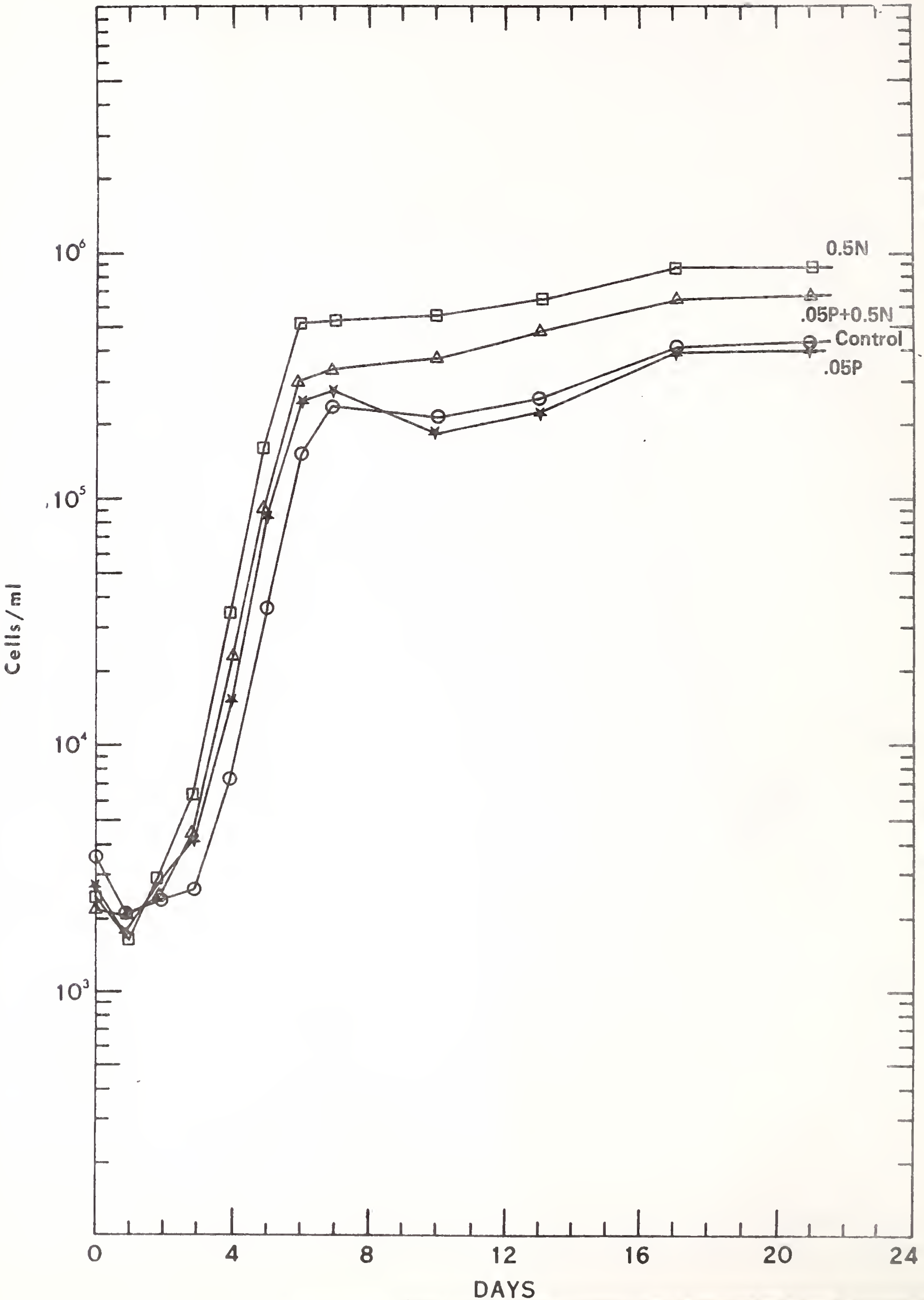


FIGURE 9

Effect of various nutrient additions to water from Station C on growth of *Selenastrum capricornutum*.

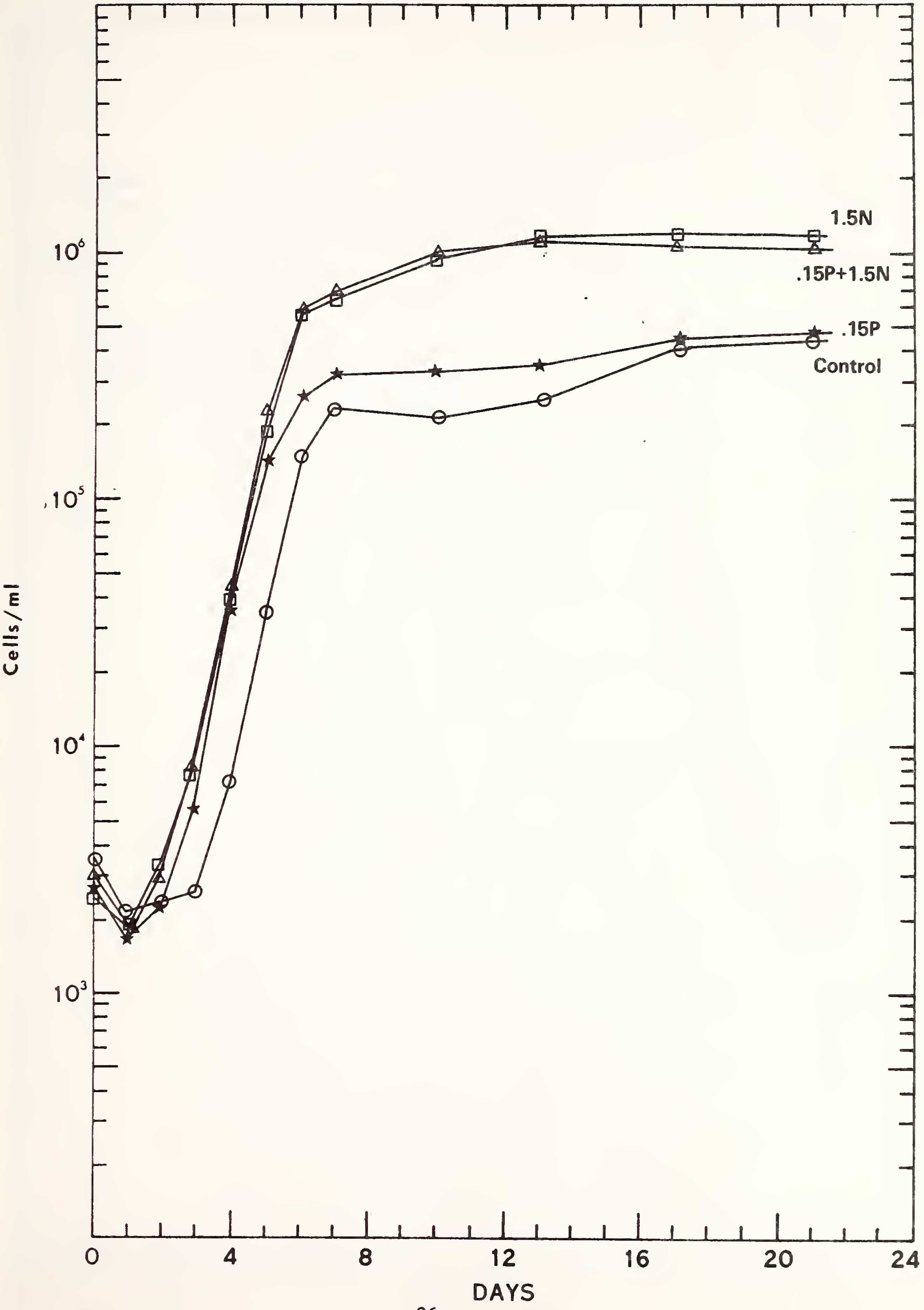


FIGURE 10

Effect of various nutrient additions to water from Station C on growth of *Selenastrum capricornutum.*

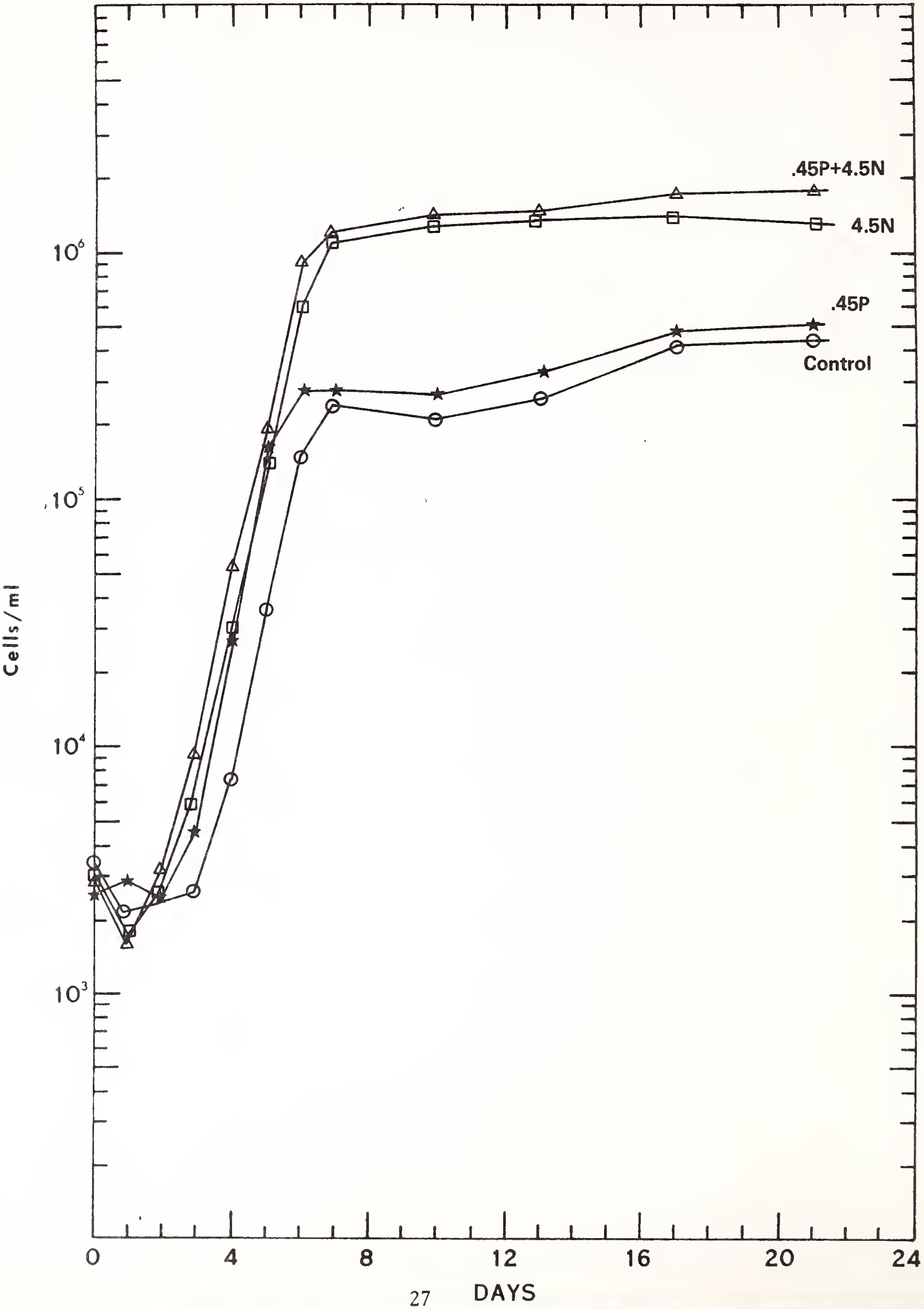


FIGURE 11

Effect of various nutrient additions to water from Station D on growth of *Selenastrum capricornutum.*

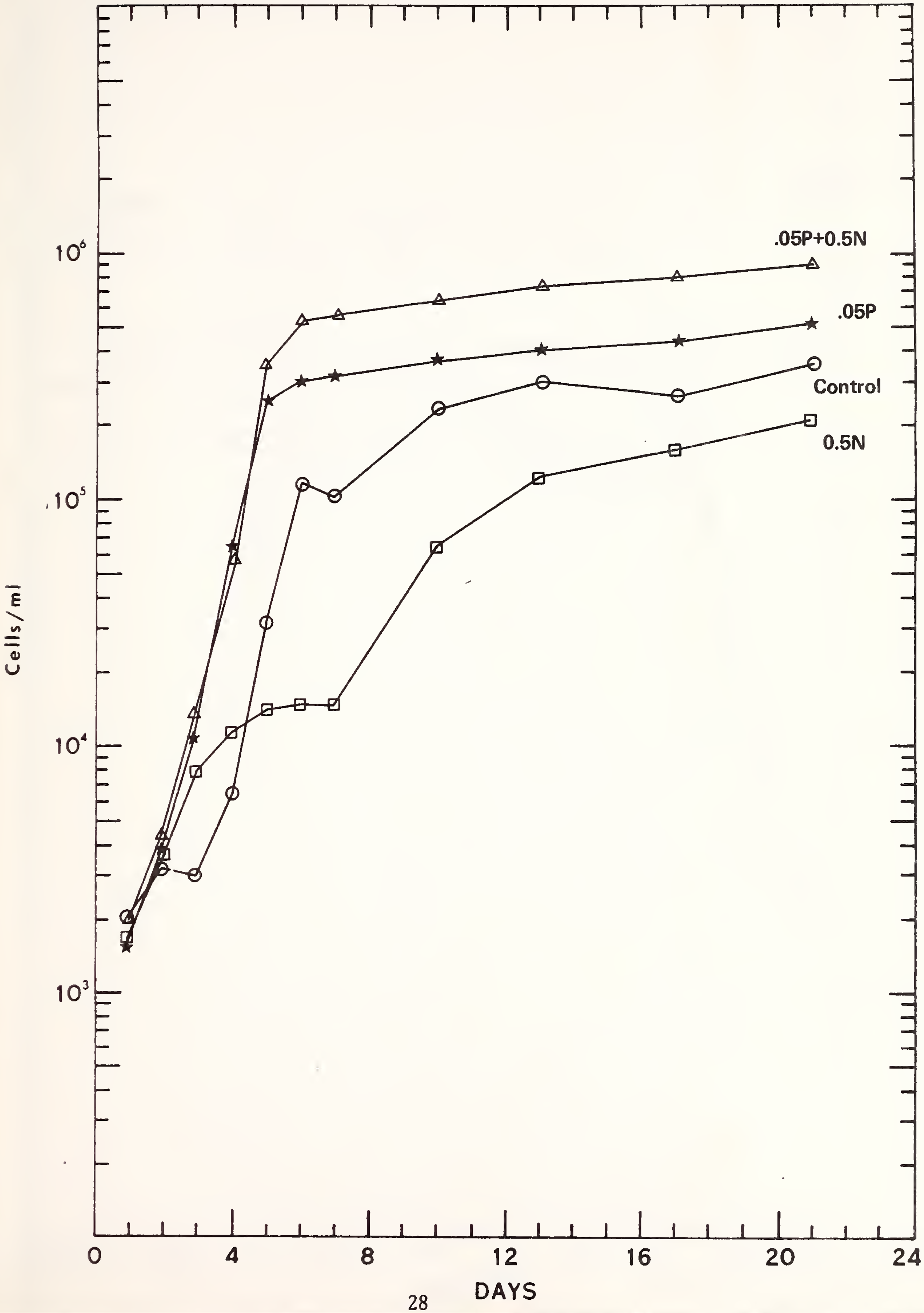


FIGURE 12

Effect of various nutrient additions to water from Station D on growth of *Selenastrum capricornutum.*

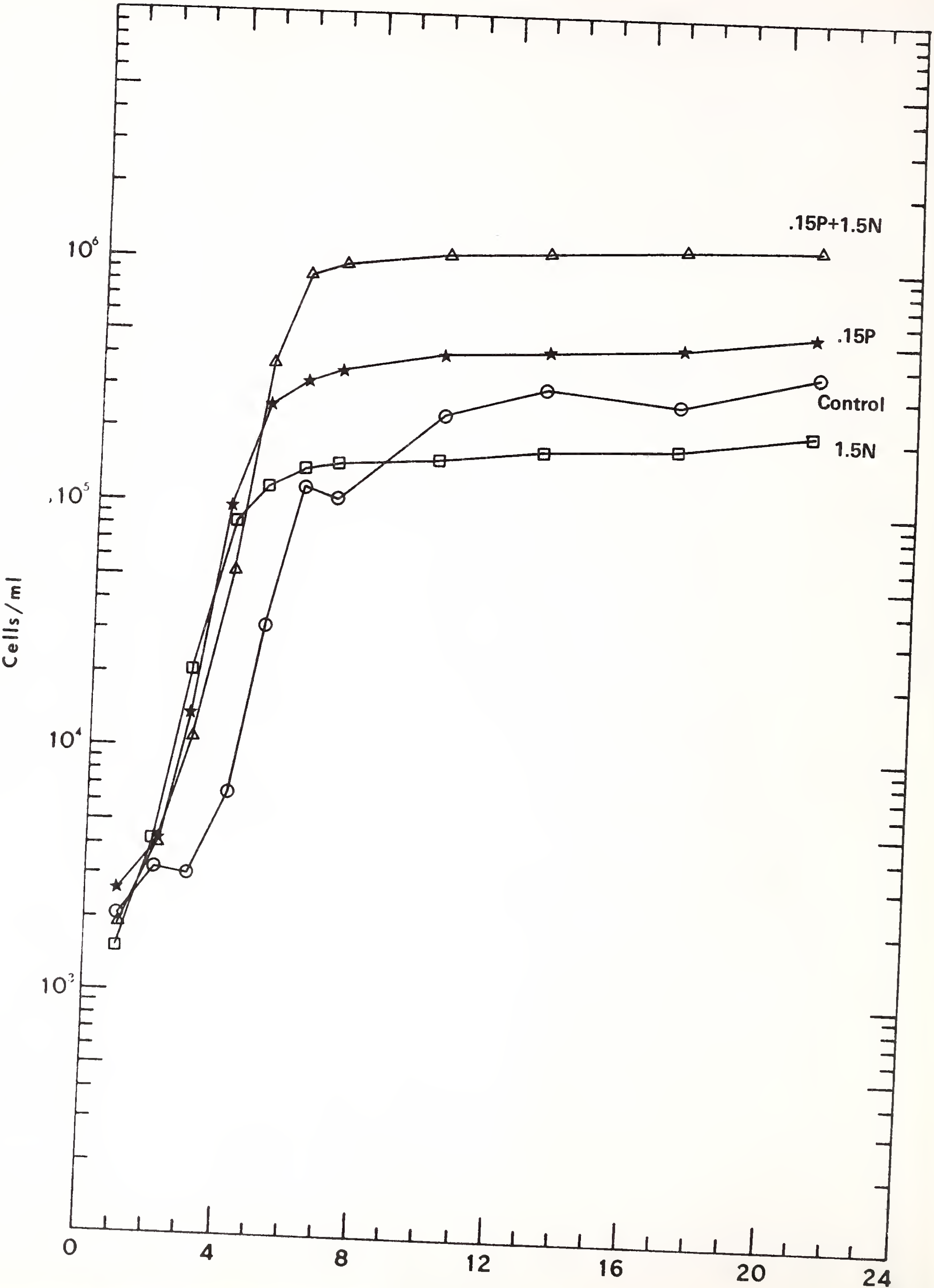


FIGURE 13

Effect of various nutrient additions to water from Station D on growth of *Selenastrum capricornutum.*

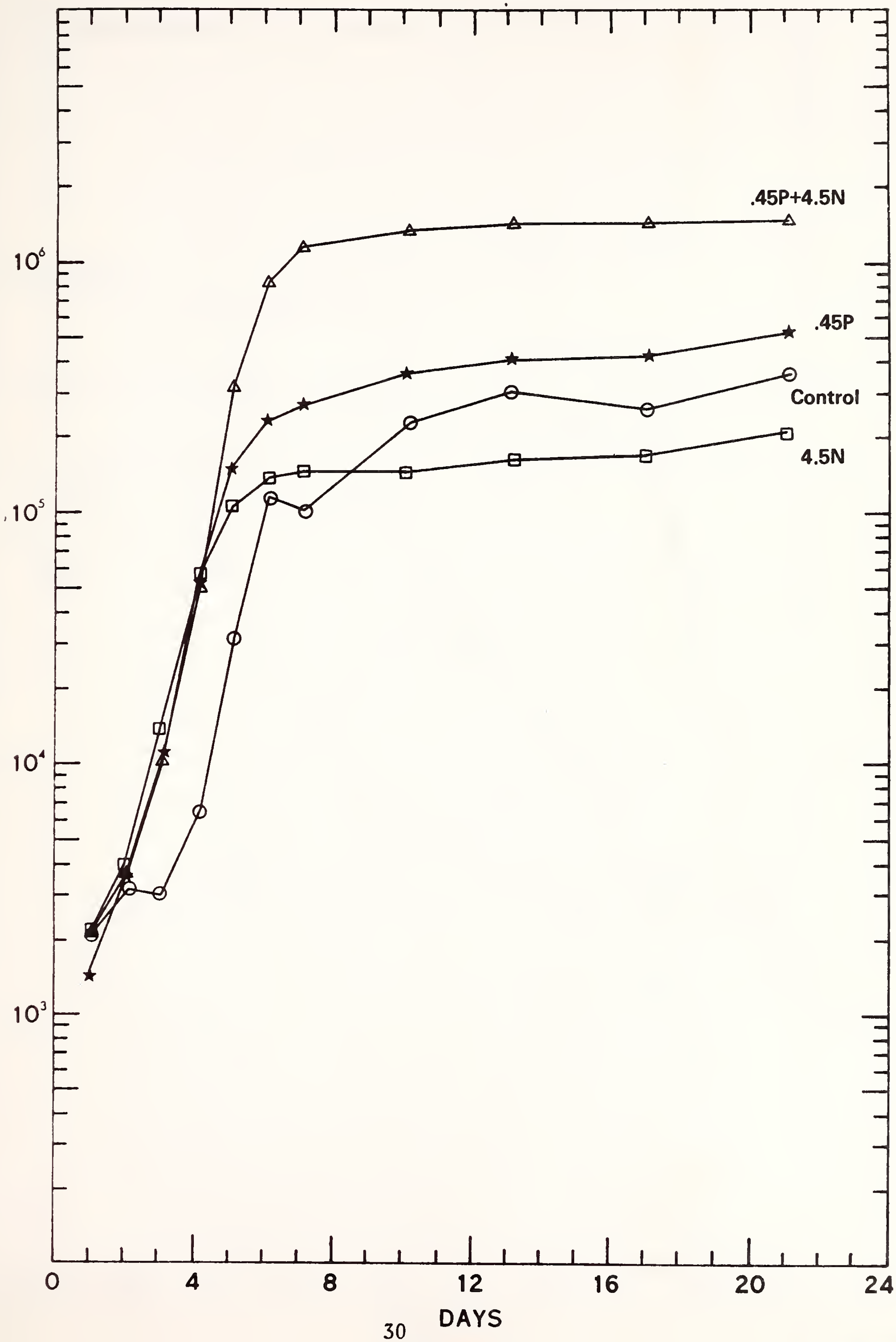


FIGURE 14

Effect of various nutrient additions to water from Station E on growth of *Selenastrum capricornutum.*

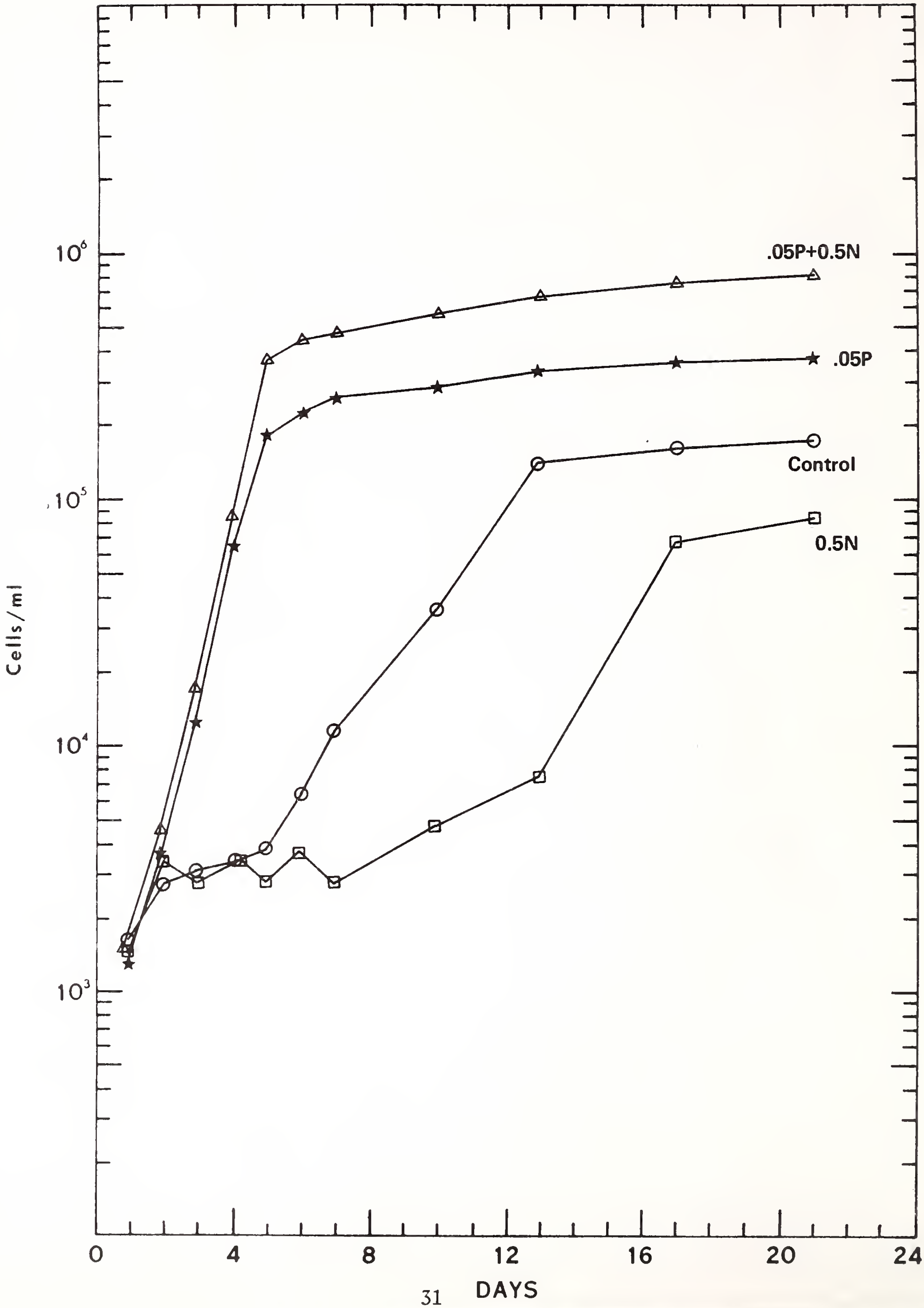


FIGURE 15

Effect of various nutrient additions to water from Station E on growth of *Selenastrum capricornutum.*

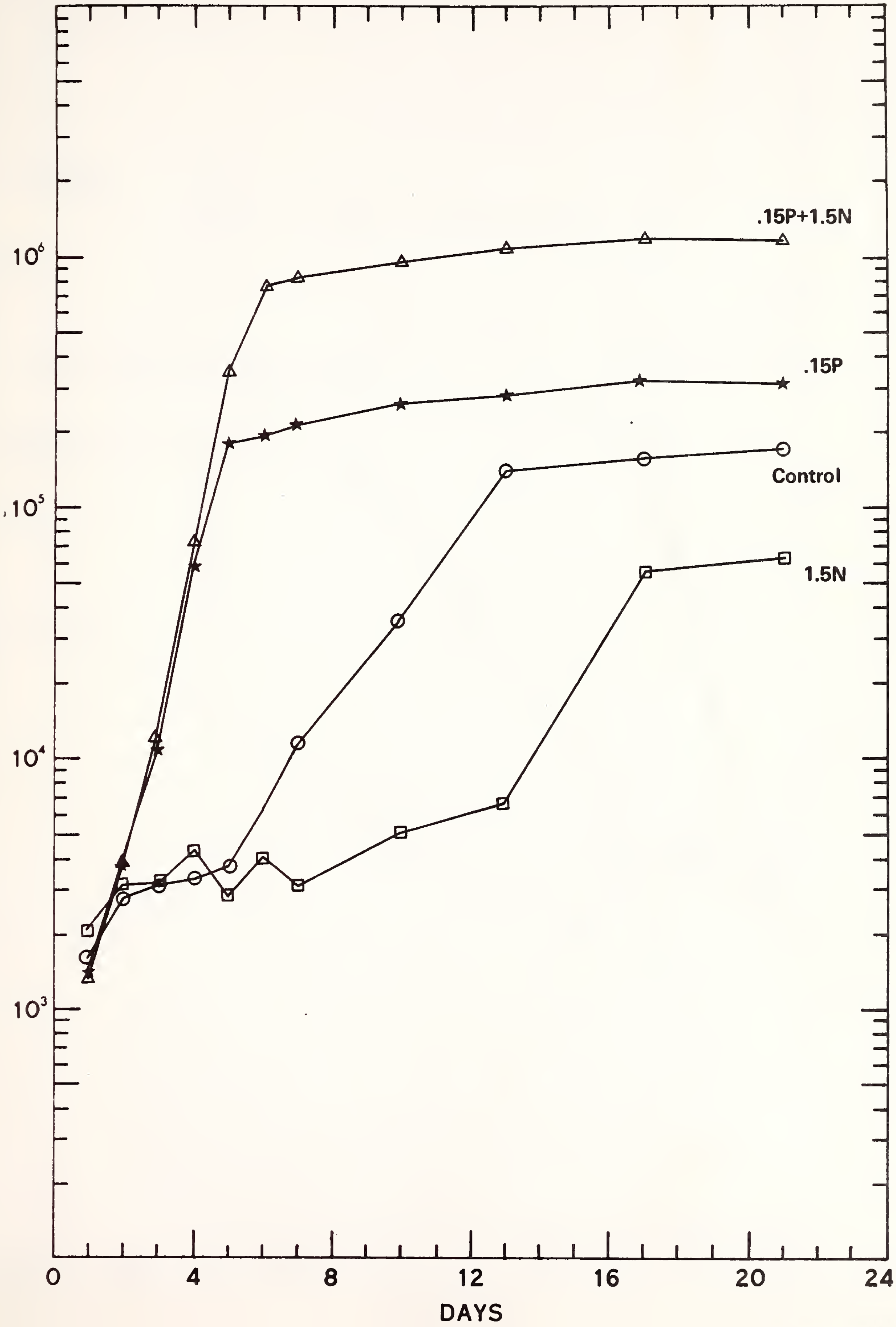


FIGURE 16

Effect of various nutrient additions to water from Station E on growth of *Selenastrum capricornutum.*

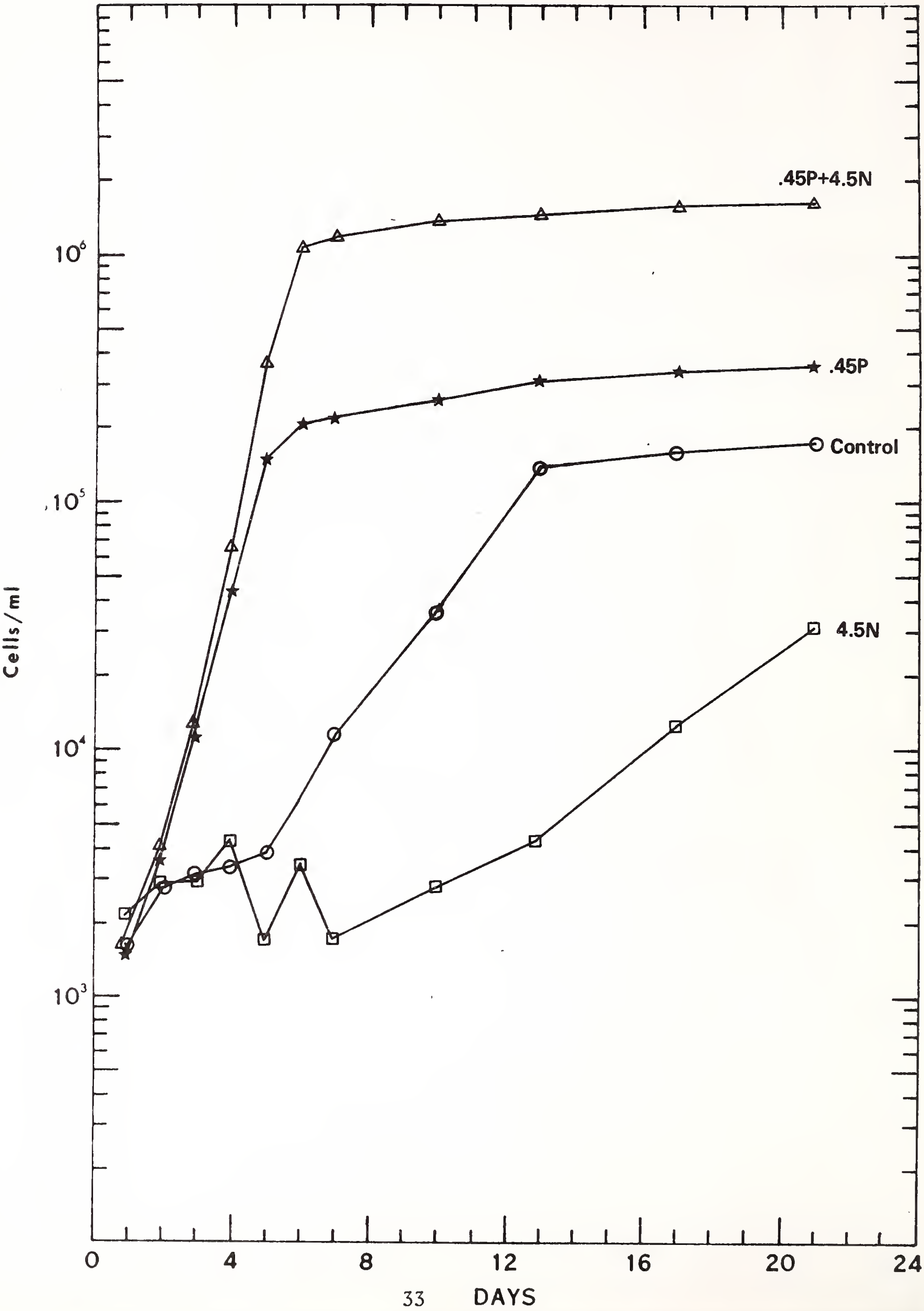


FIGURE 17

Effect of various nutrient additions to water from Station F on growth of *Selenastrum capricornutum*.

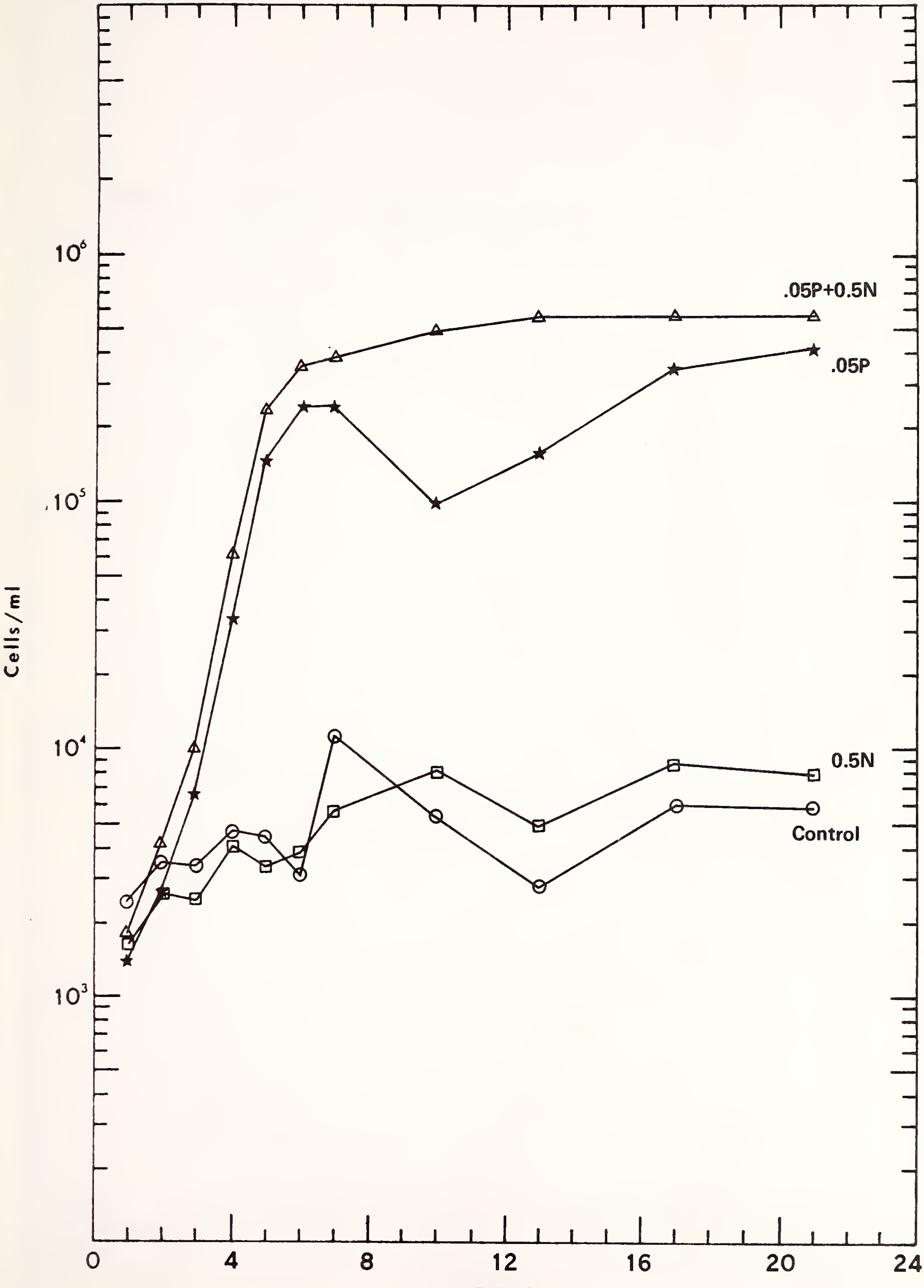


FIGURE 18

Effect of various nutrient additions to water from Station F on growth of *Selenastrum capricornutum*.

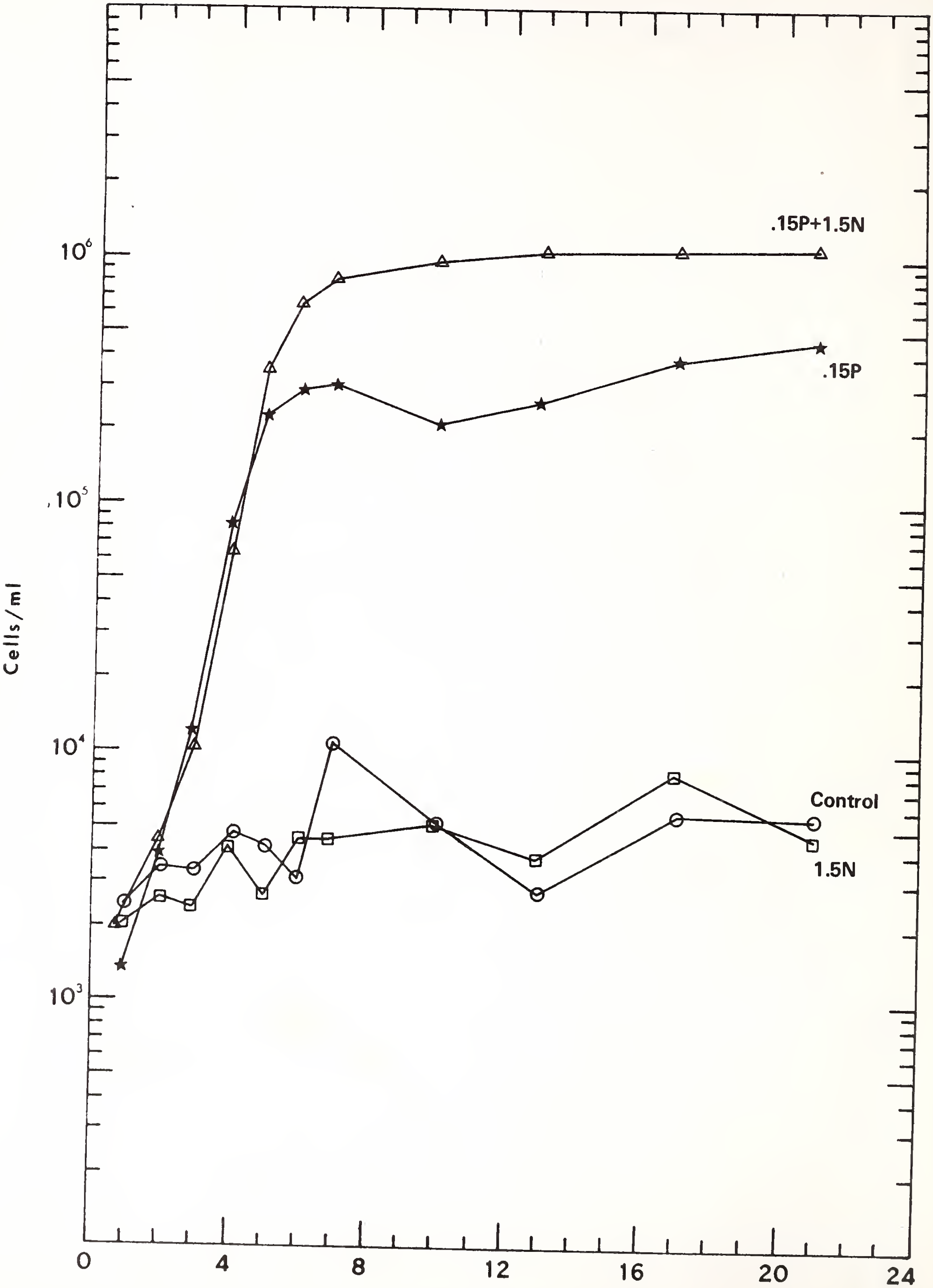


FIGURE 19

Effect of various nutrient additions to water from Station F on growth of *Selenastrum capricornutum.*

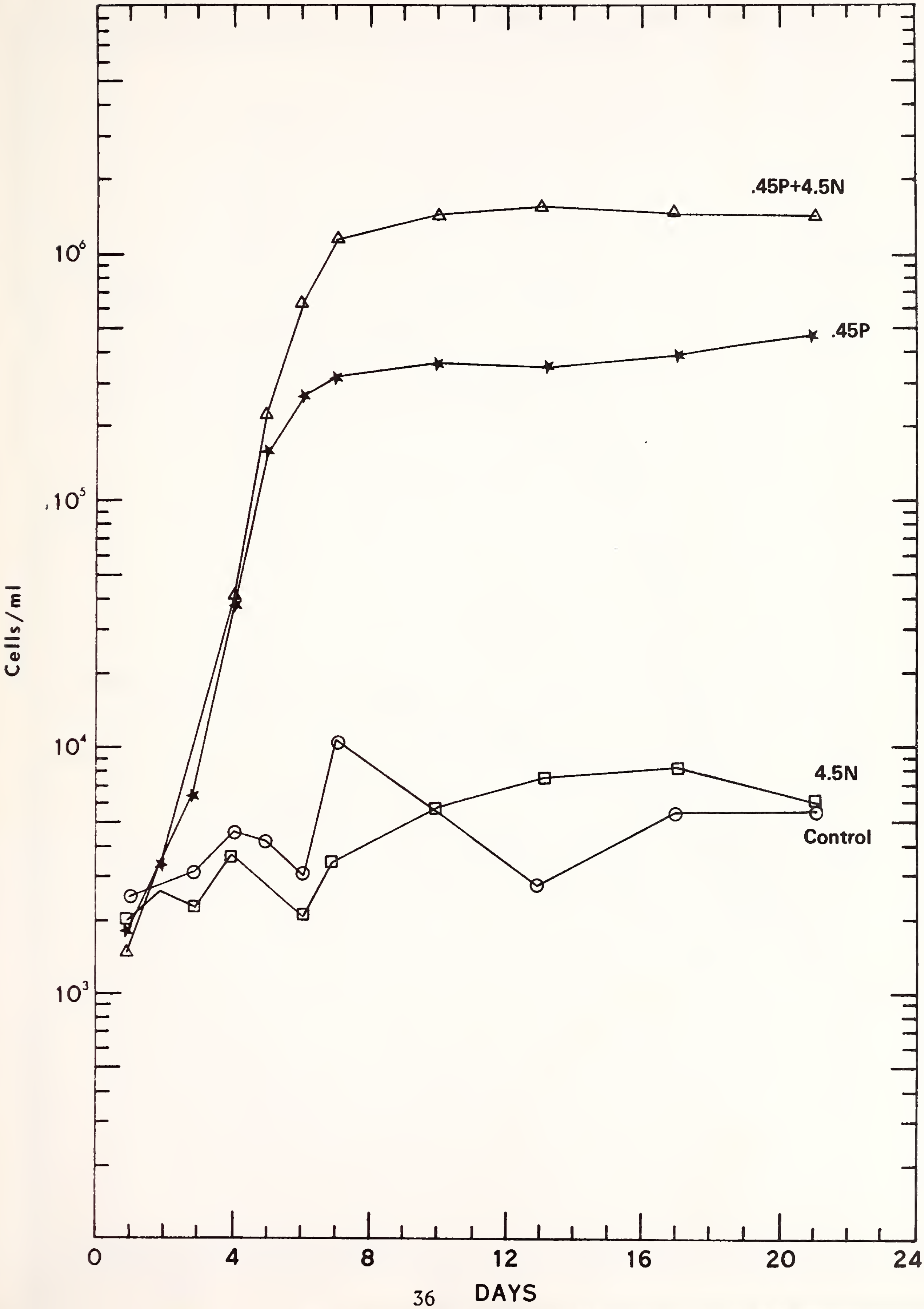


FIGURE 20

Effect of various nutrient additions to water from Station G on growth of *Selenastrum capricornutum*.

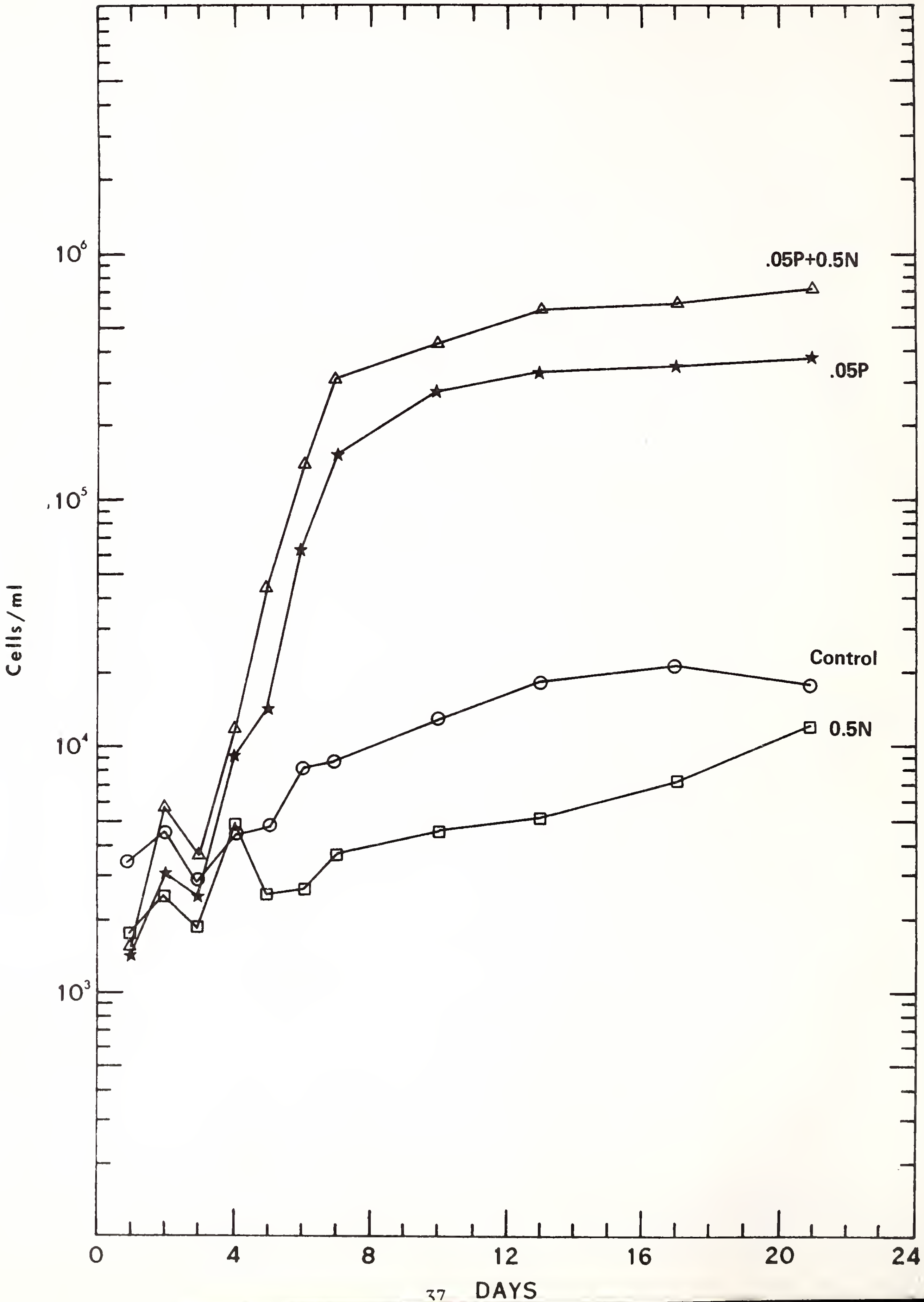


FIGURE 21

Effect of various nutrient additions to water from Station G on growth of *Selenastrum capricornutum*.

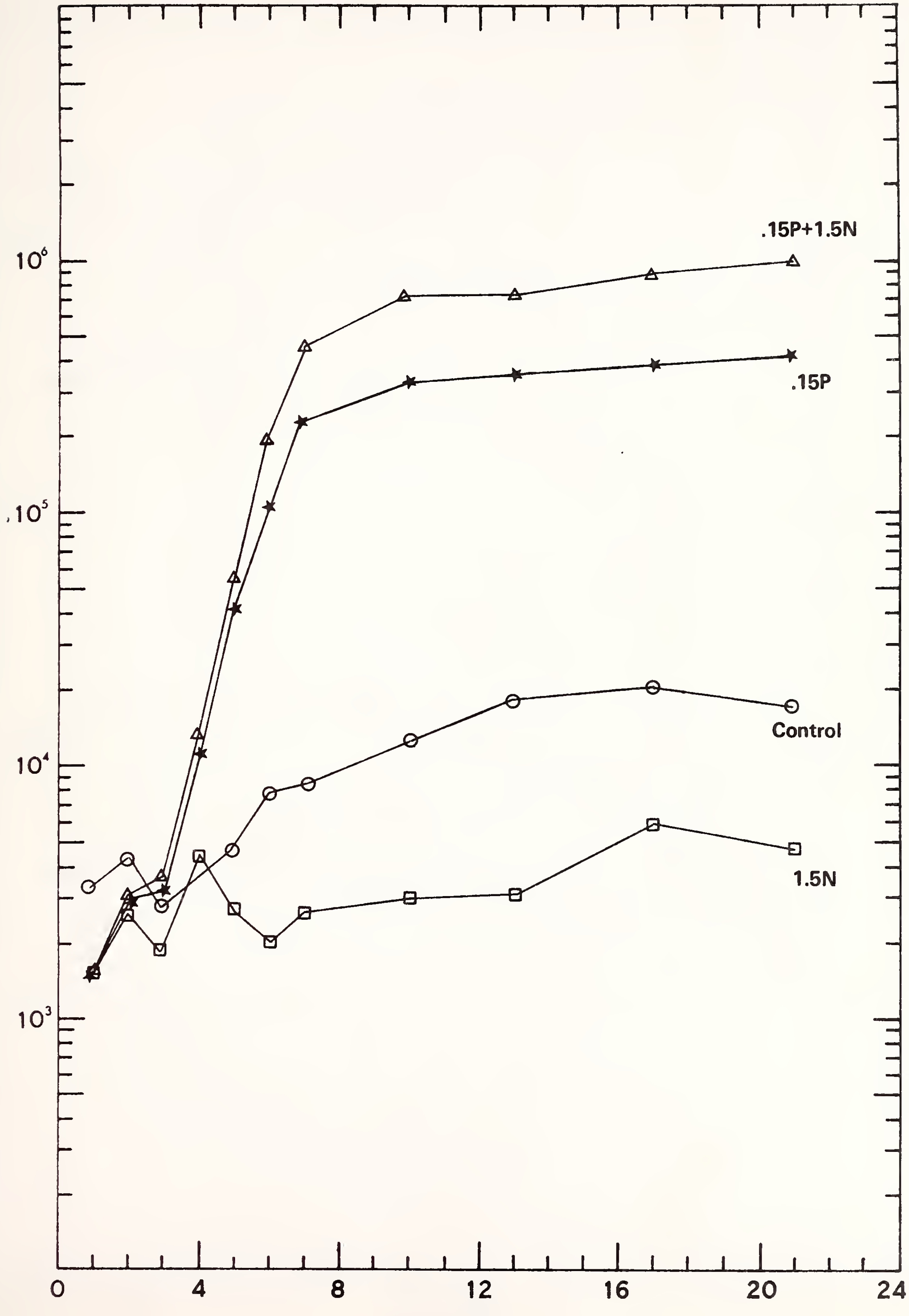


FIGURE 22

Effect of various nutrient additions to water from Station G on growth of *Selenastrum capricornutum.*

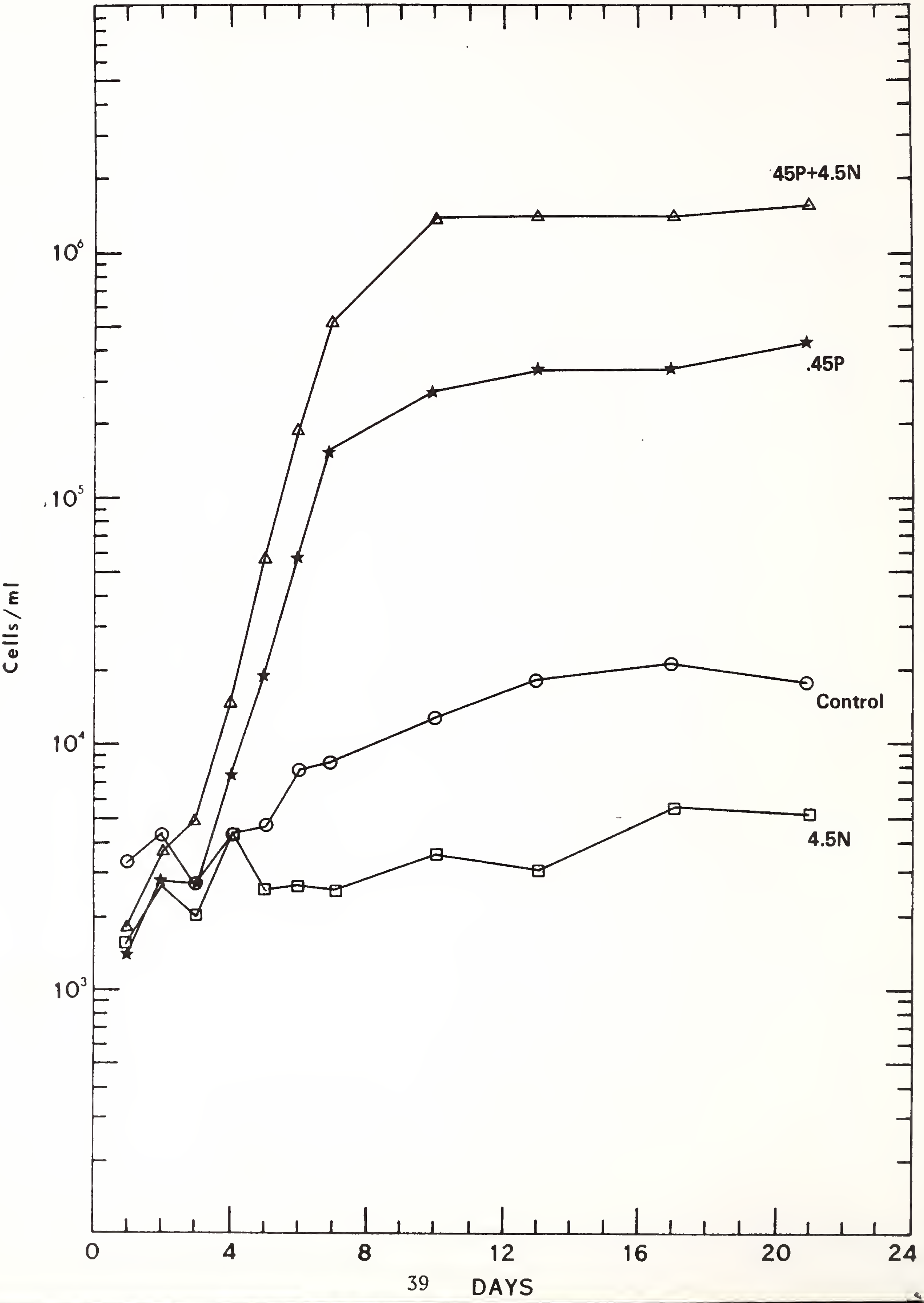


FIGURE 23

Effect of various nutrient additions to water from Station H on growth of *Selenastrum capricornutum.*

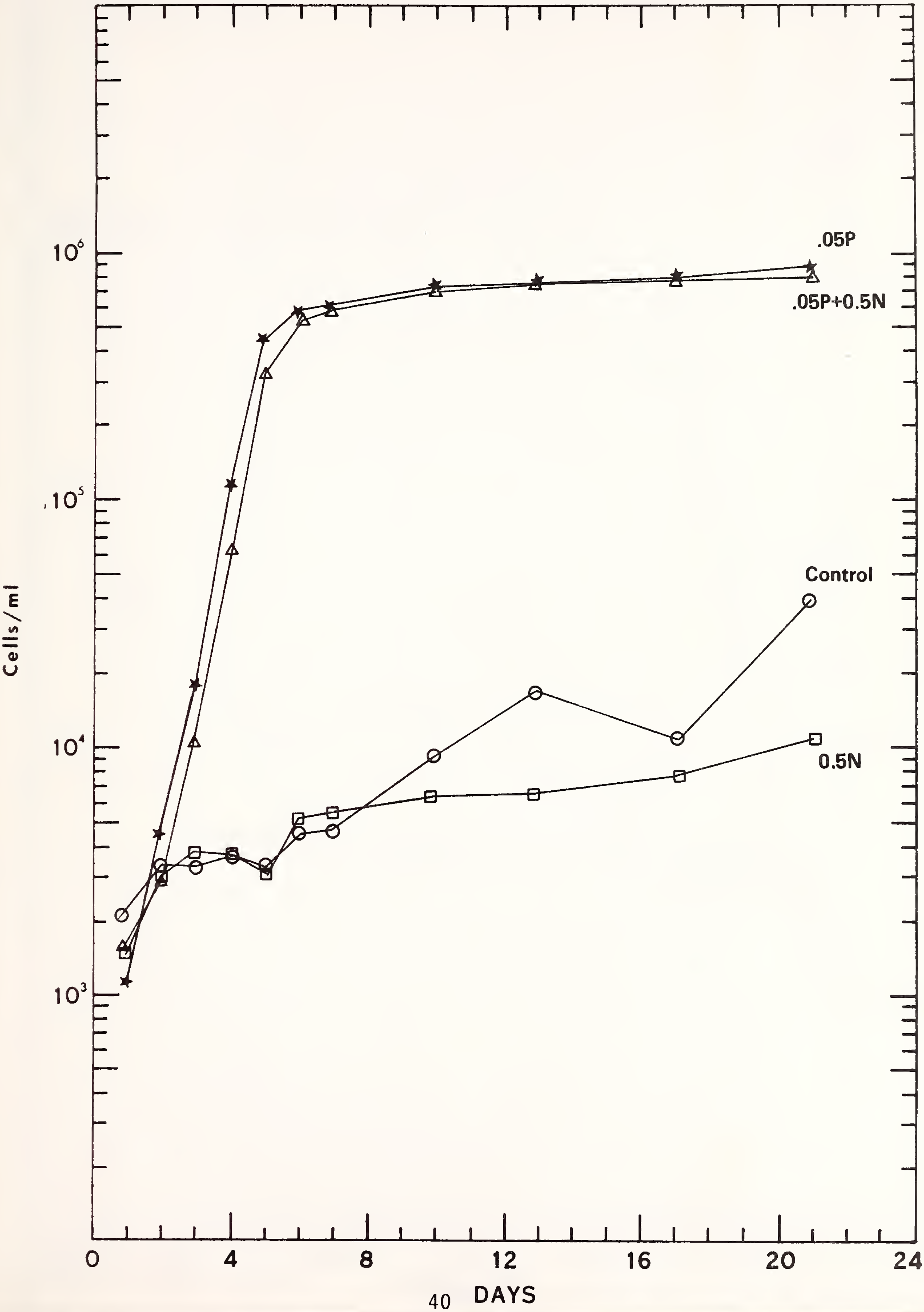


FIGURE 24

Effect of various nutrient additions to water from Station H on growth of *Selenastrum capricornutum.*

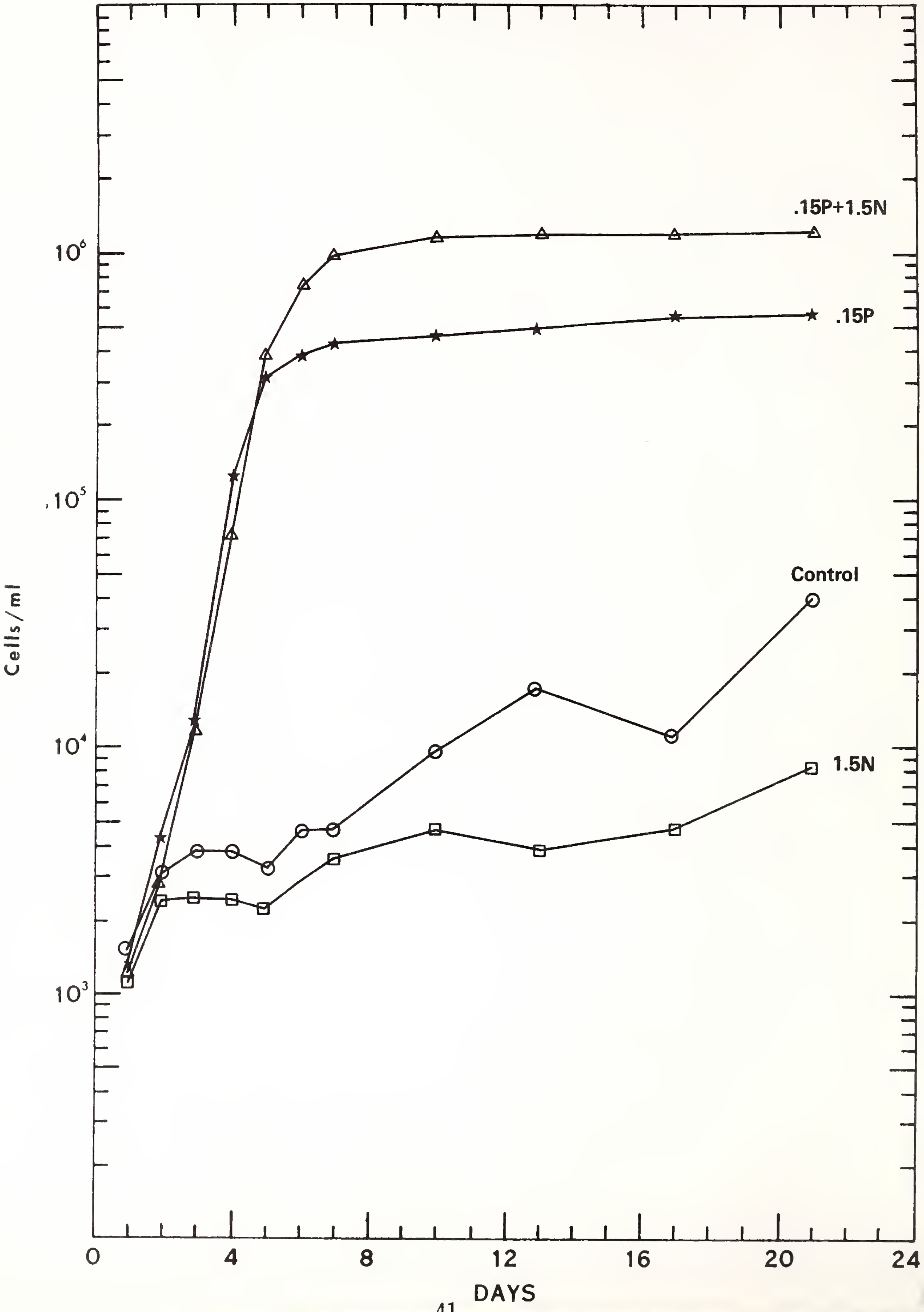


FIGURE 25

Effect of various nutrient additions to water from Station H on growth of *Selenastrum capricornutum*.

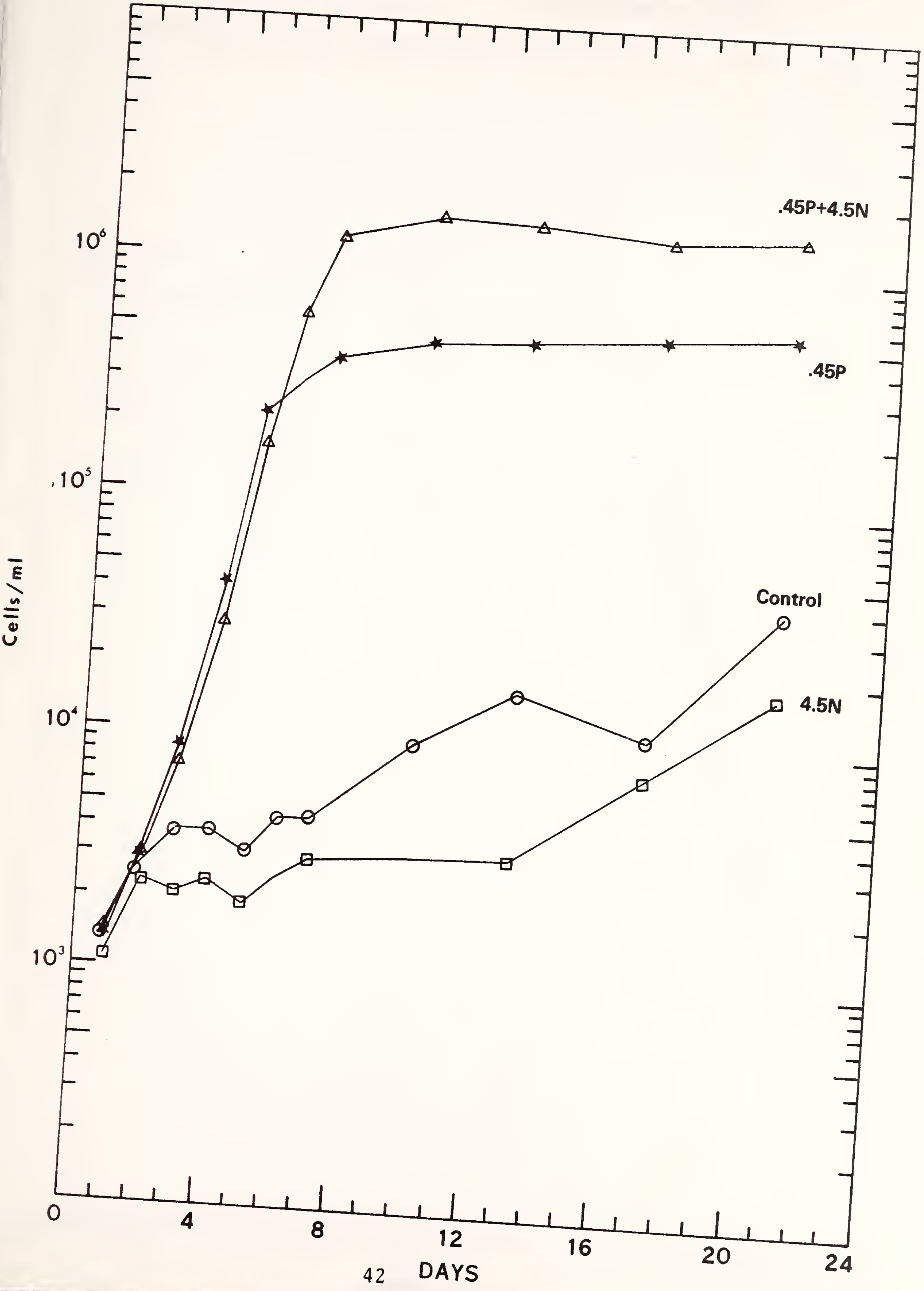


FIGURE 26

Effect of various nutrient additions to water from Station IA on growth of *Selenastrum capricornutum*.

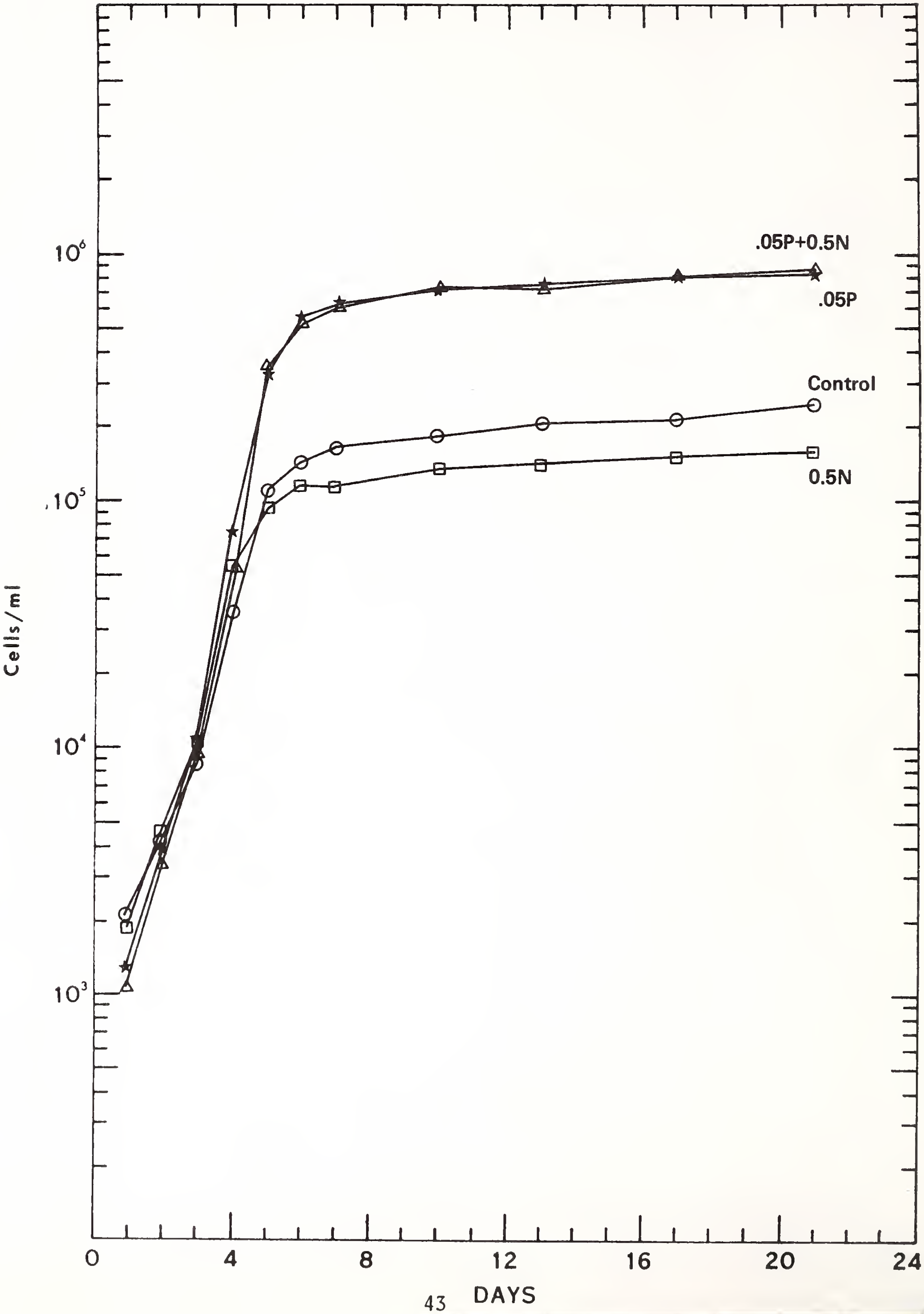


FIGURE 27

Effect of various nutrient additions to water from Station IA on growth of *Selenastrum capricornutum.*

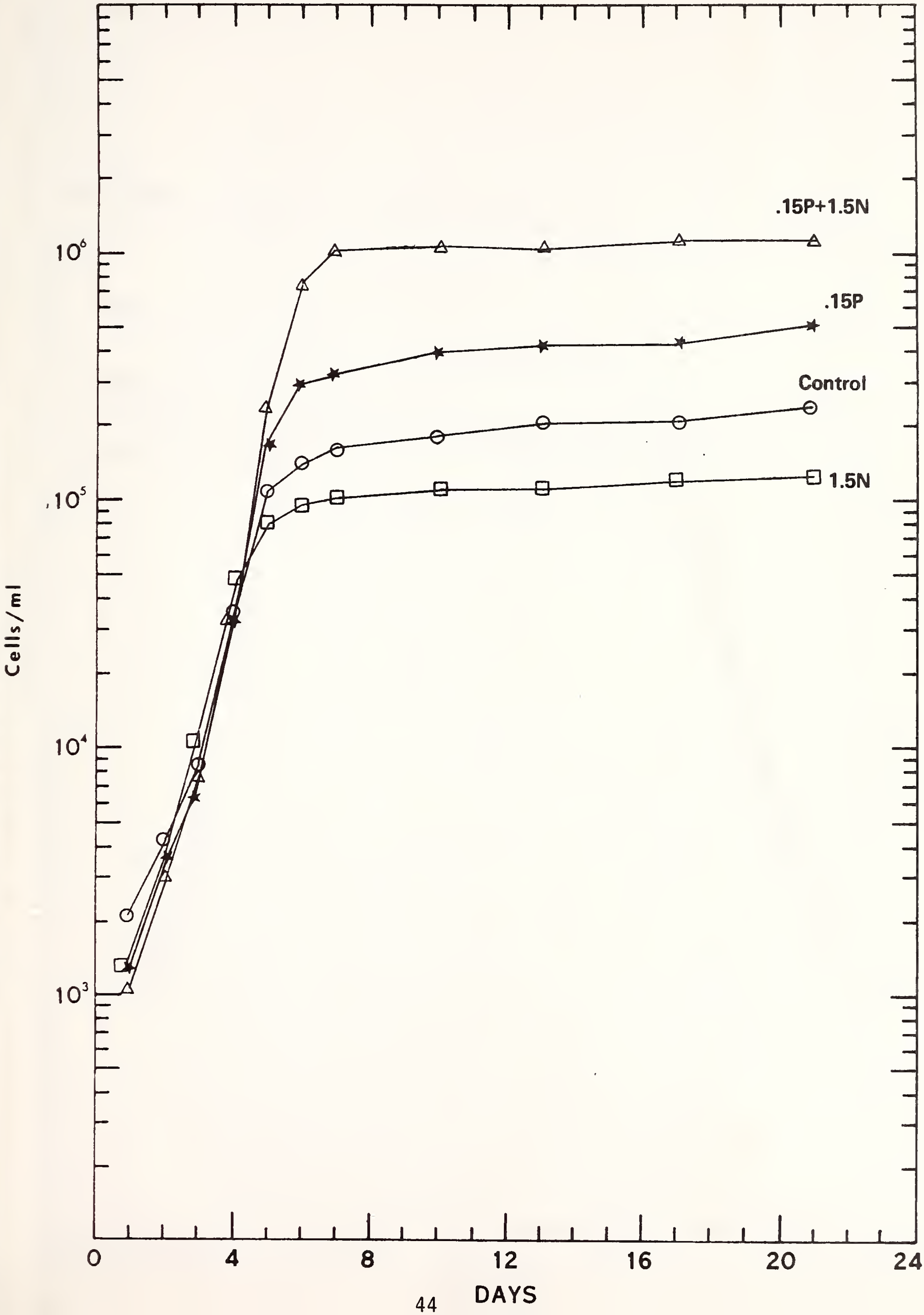


FIGURE 28

Effect of various nutrient additions to water from Station IA on growth of *Selenastrum capricornutum.*

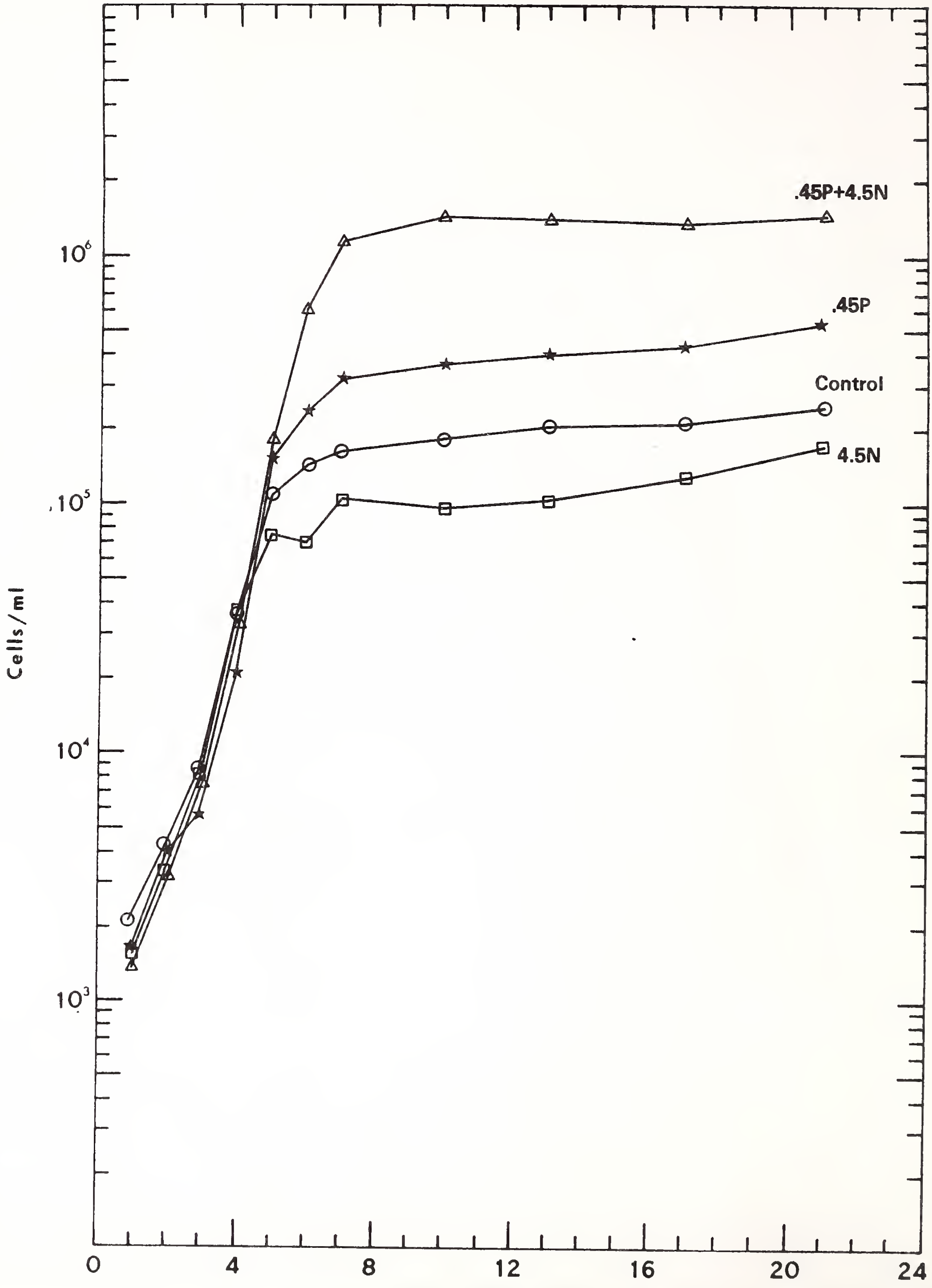


FIGURE 29

Effect of various nutrient additions to water from Station N on growth of *Selenastrum capricornutum.*

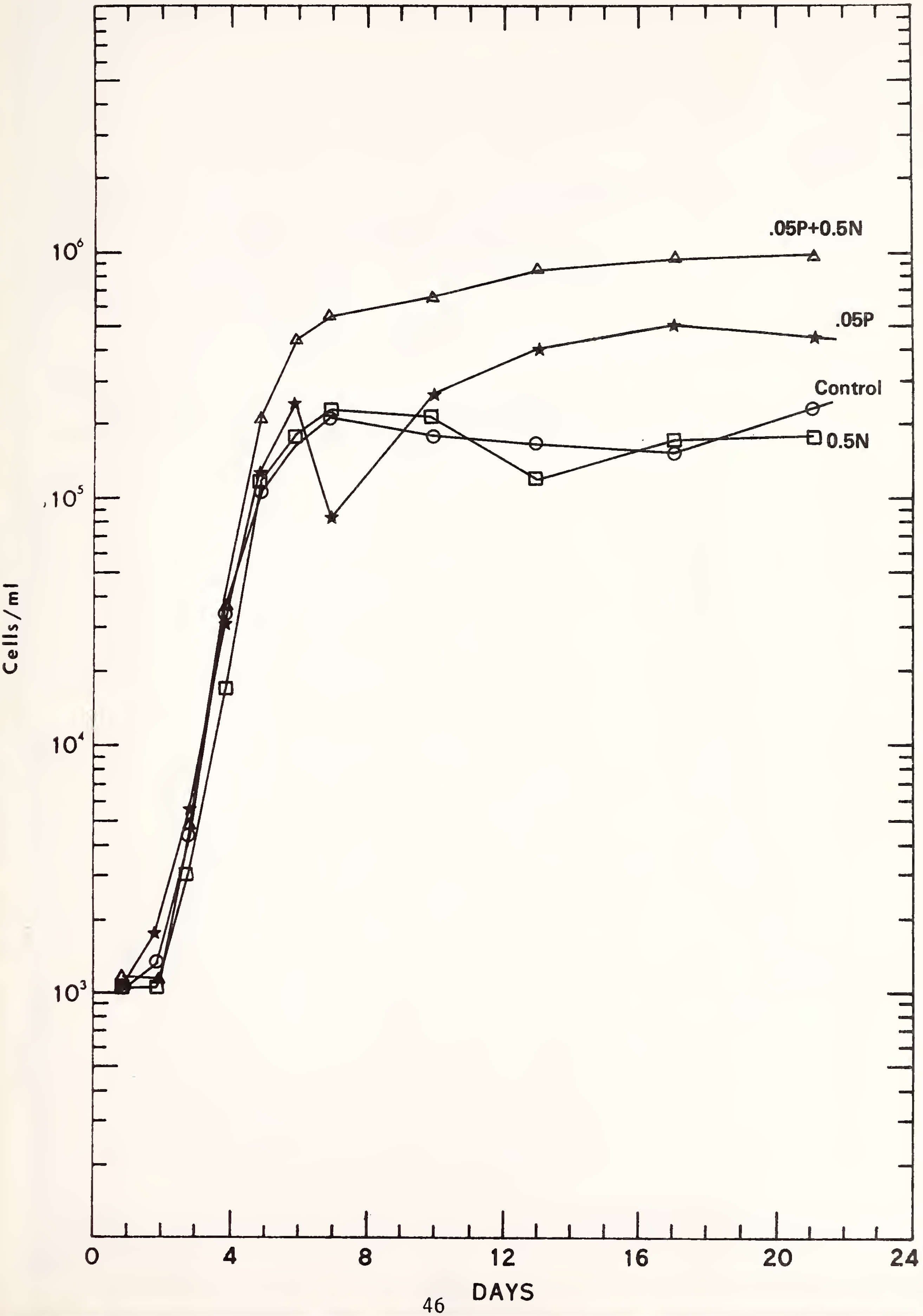


FIGURE 30

Effect of various nutrient additions to water from Station N on growth of *Selenastrum capricornutum.*

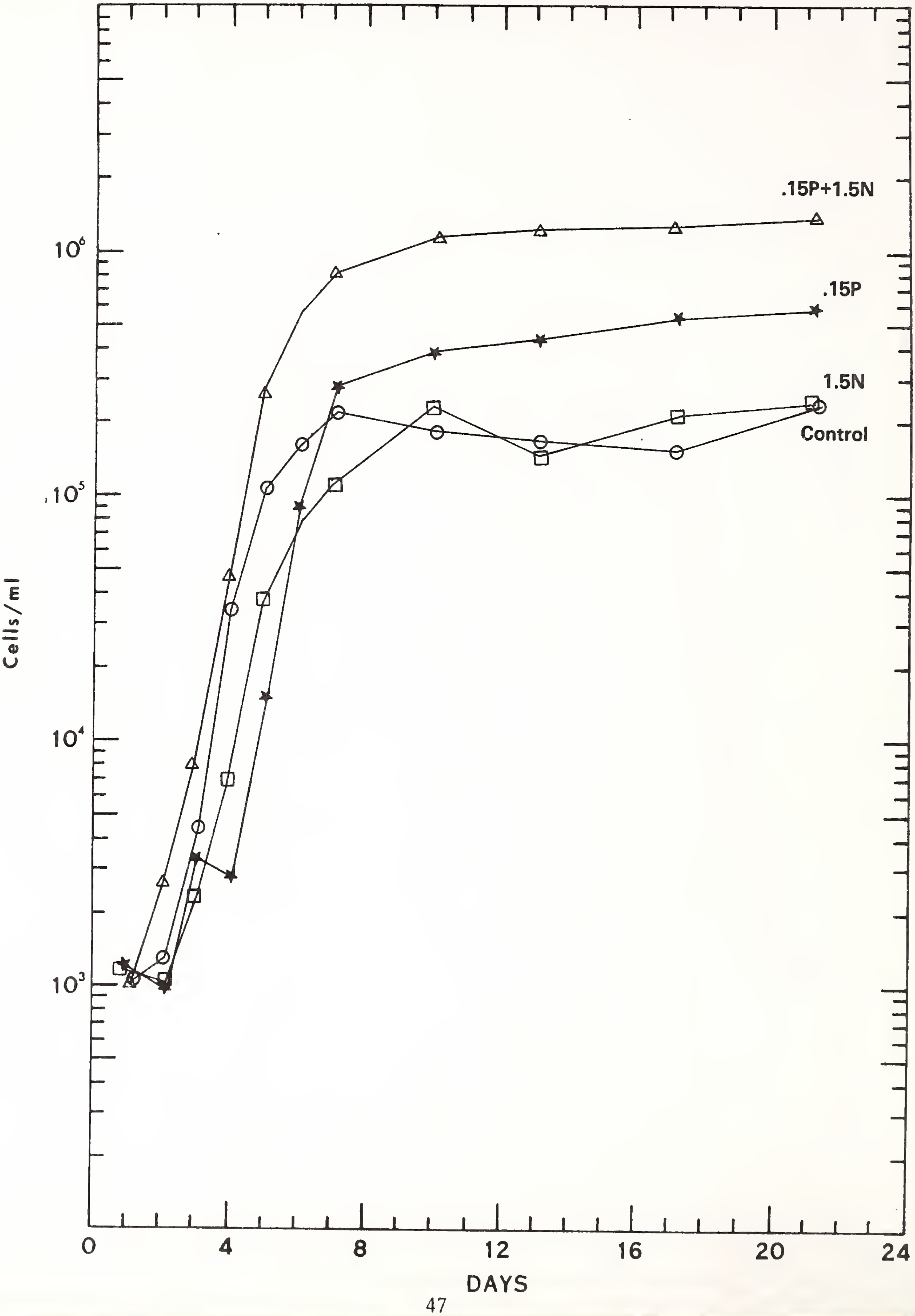


FIGURE 31

Effect of various nutrient additions to water from Station N on growth of *Selenastrum capricornutum.*

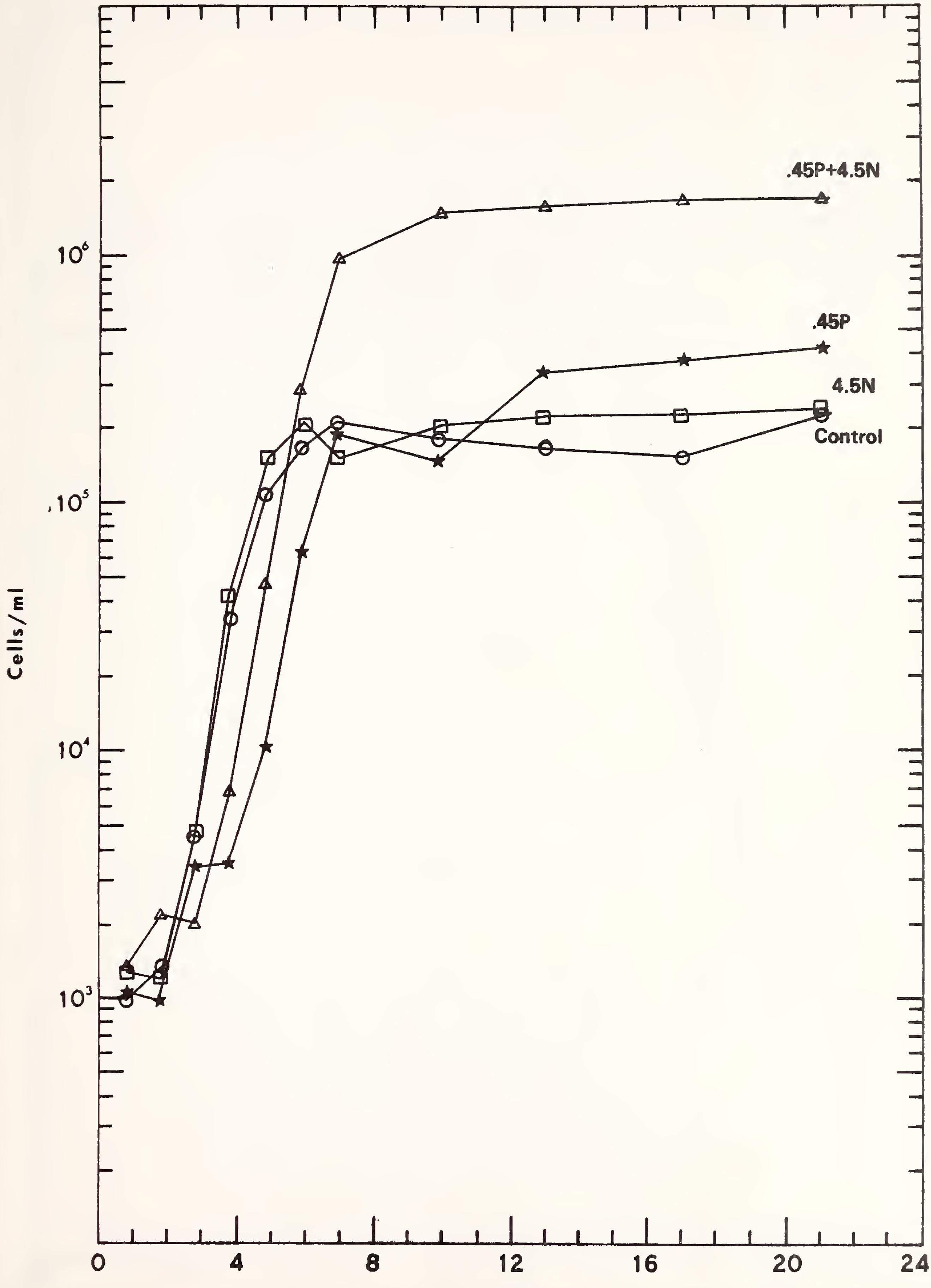


FIGURE 32

Effect of various nutrient additions to water from Station J on growth of *Selenastrum capricornutum.*

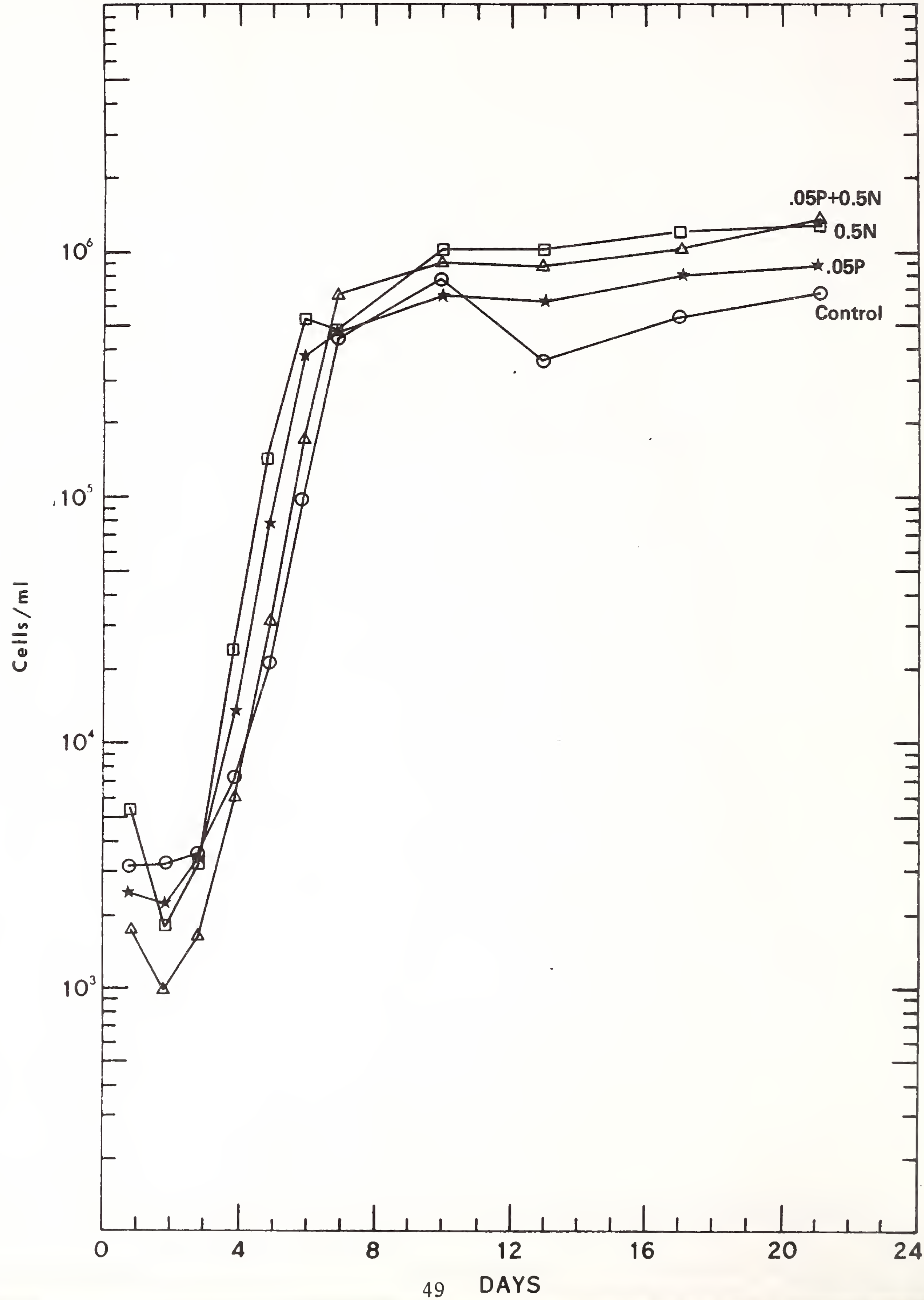


FIGURE 33

Effect of various nutrient additions to water from Station J on growth of *Selenastrum capricornutum.*

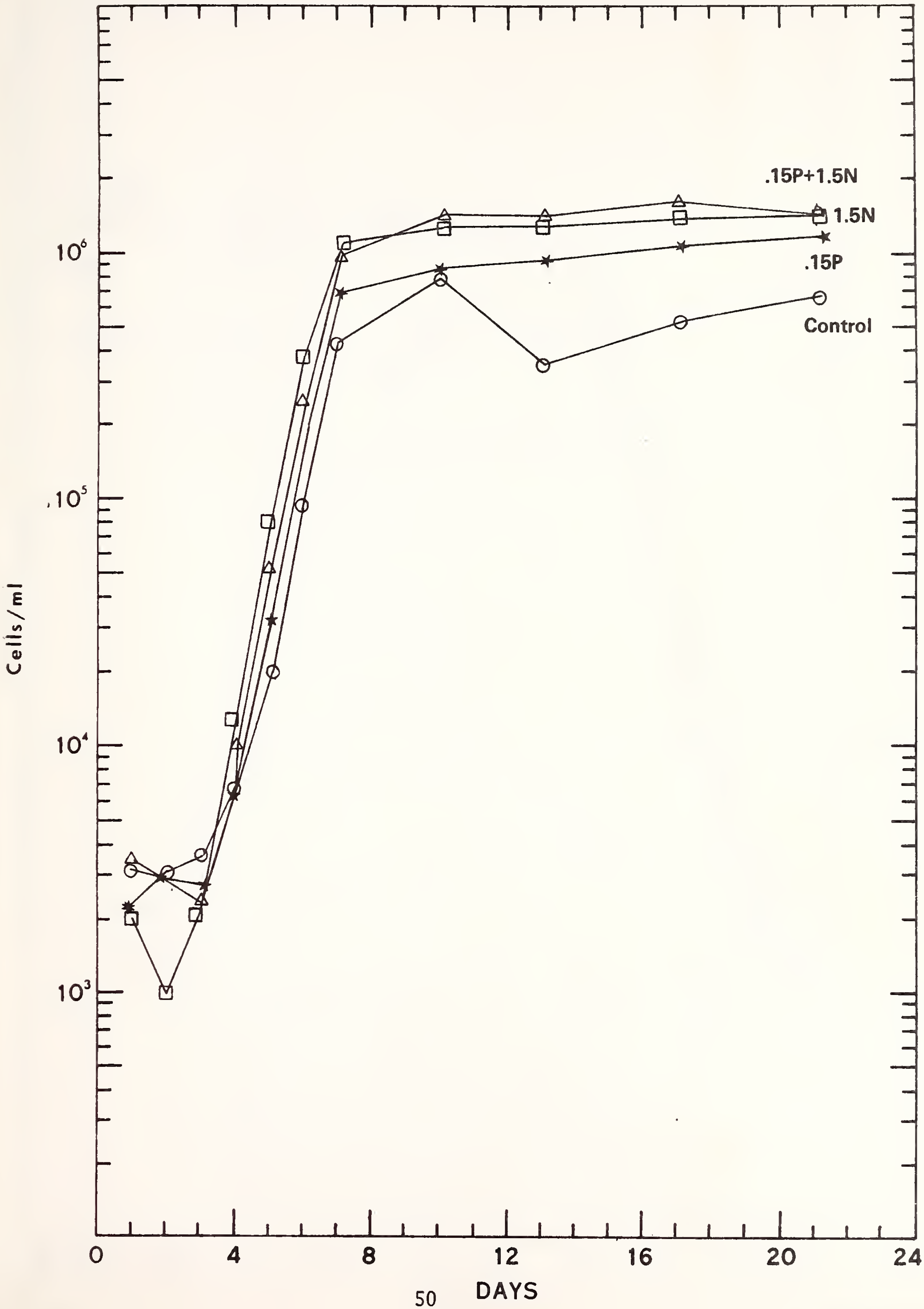


FIGURE 34

Effect of various nutrient additions to water from Station J on growth of *Selenastrum capricornutum.*

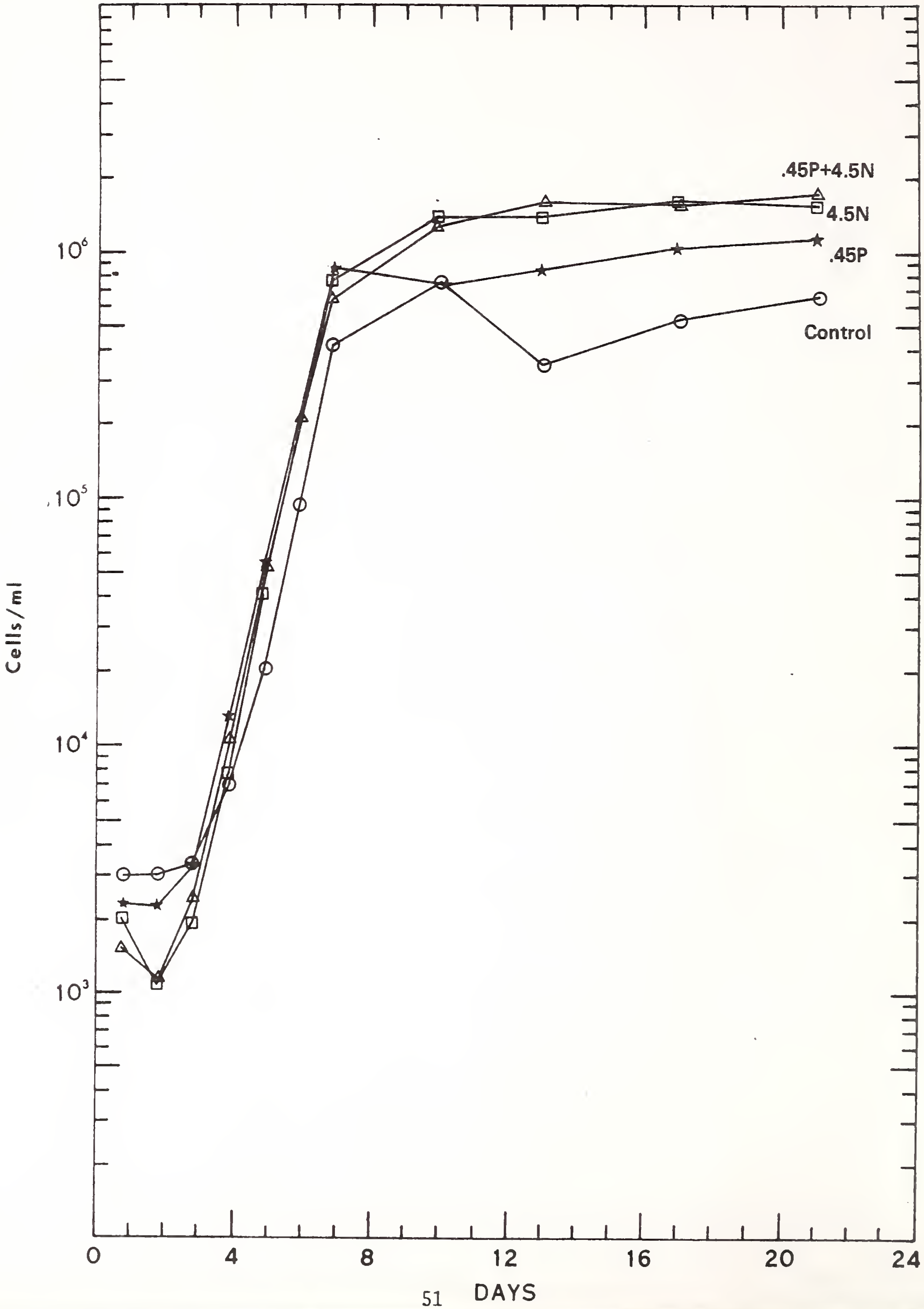


FIGURE 35

Effect of various nutrient additions to water from Station K on growth of *Selenastrum capricornutum.*

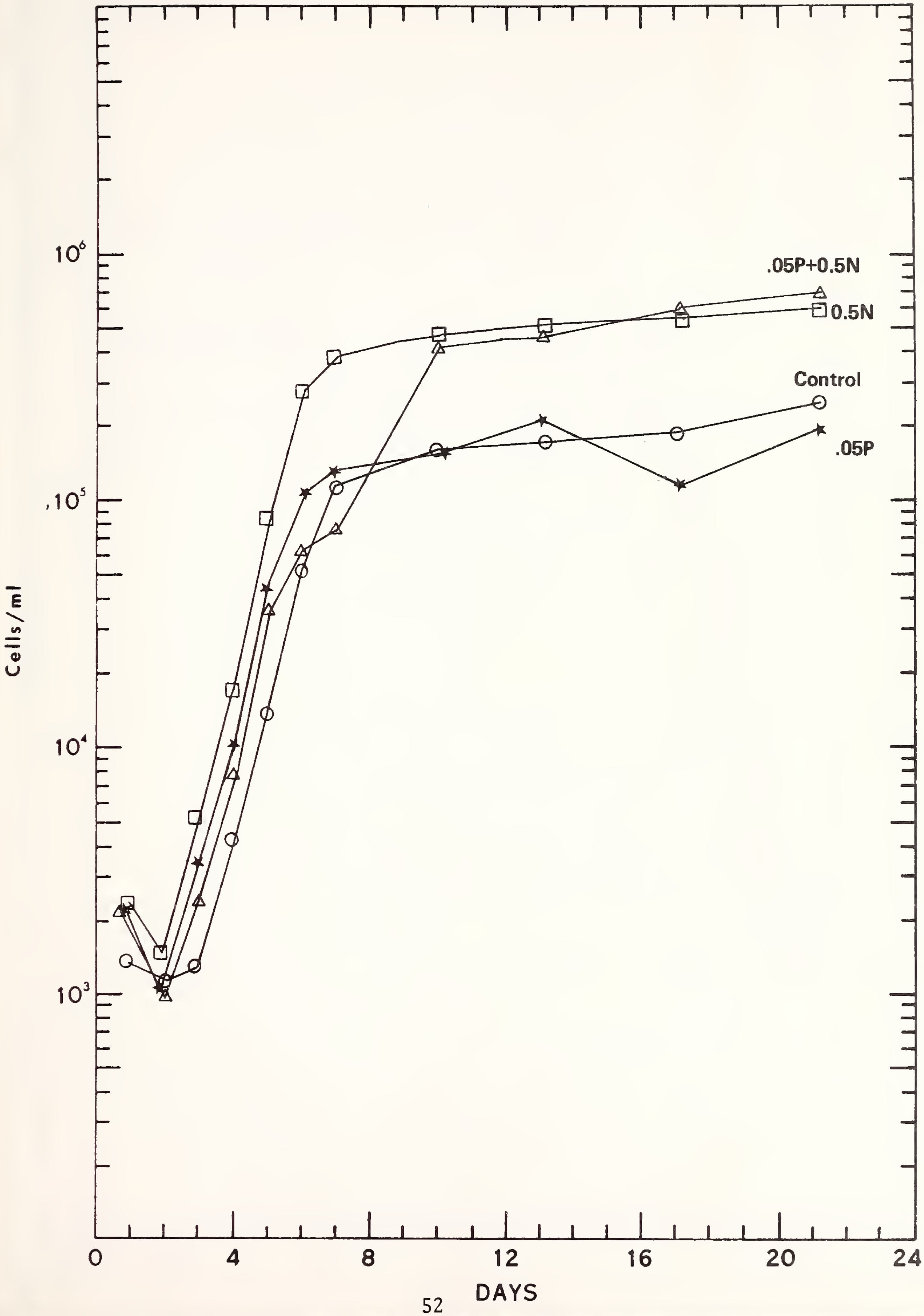


FIGURE 36

Effect of various nutrient additions to water from Station K on growth of *Selenastrum capricornutum.*

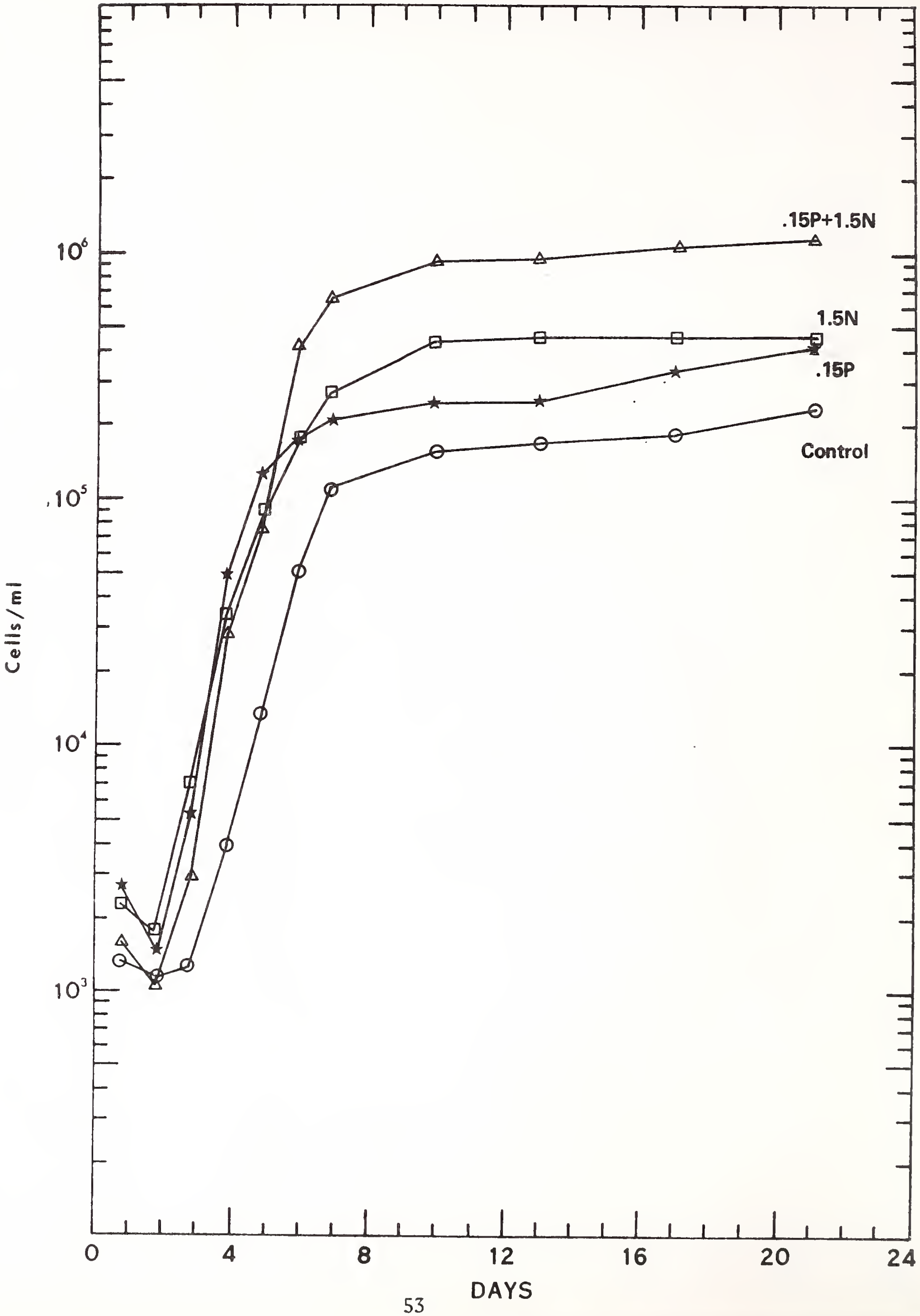


FIGURE 37

Effect of various nutrient additions to water from Station K on growth of *Selenastrum capricornutum.*

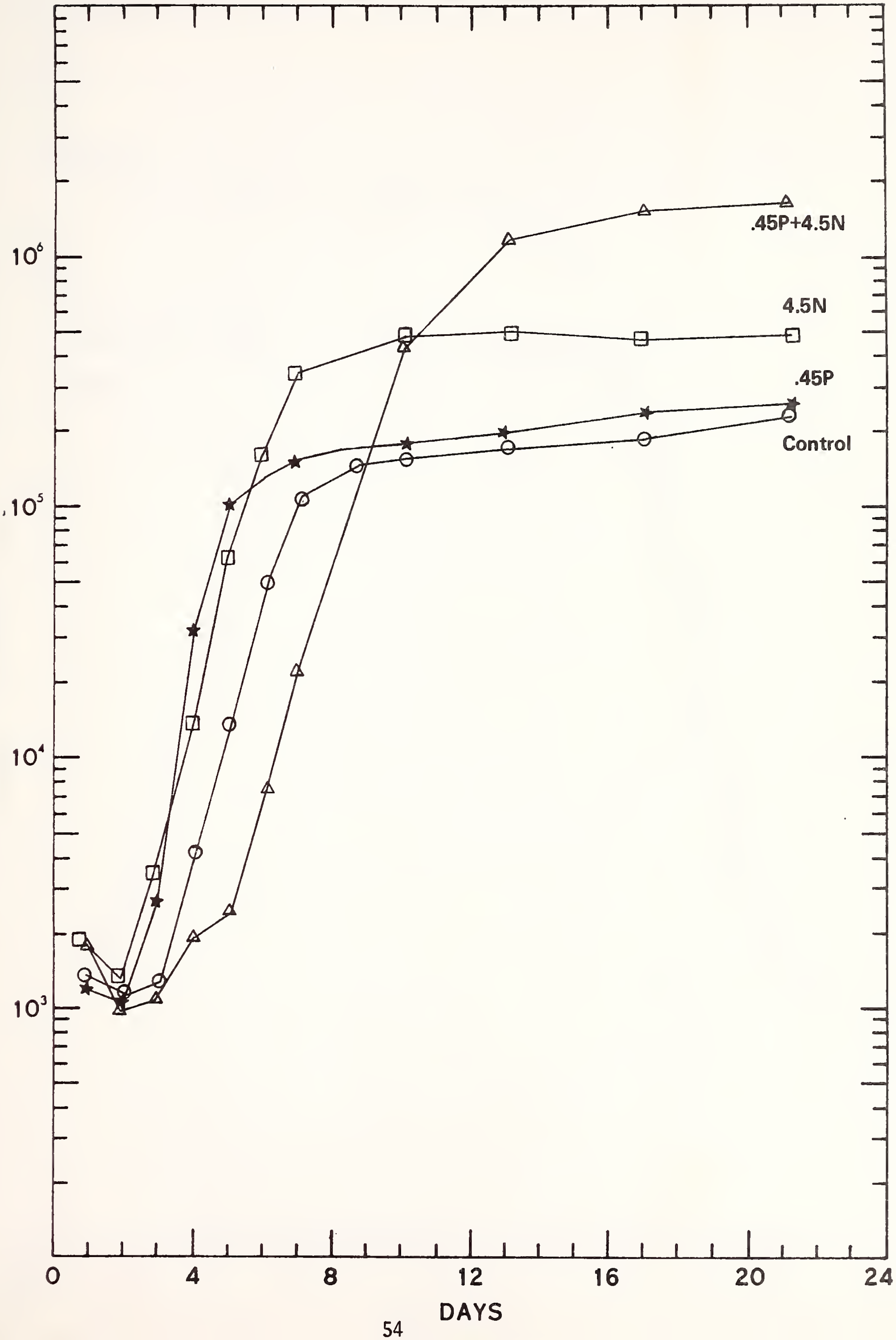


FIGURE 38

Effect of various nutrient additions to water from Station X on growth of *Selenastrum capricornutum.*

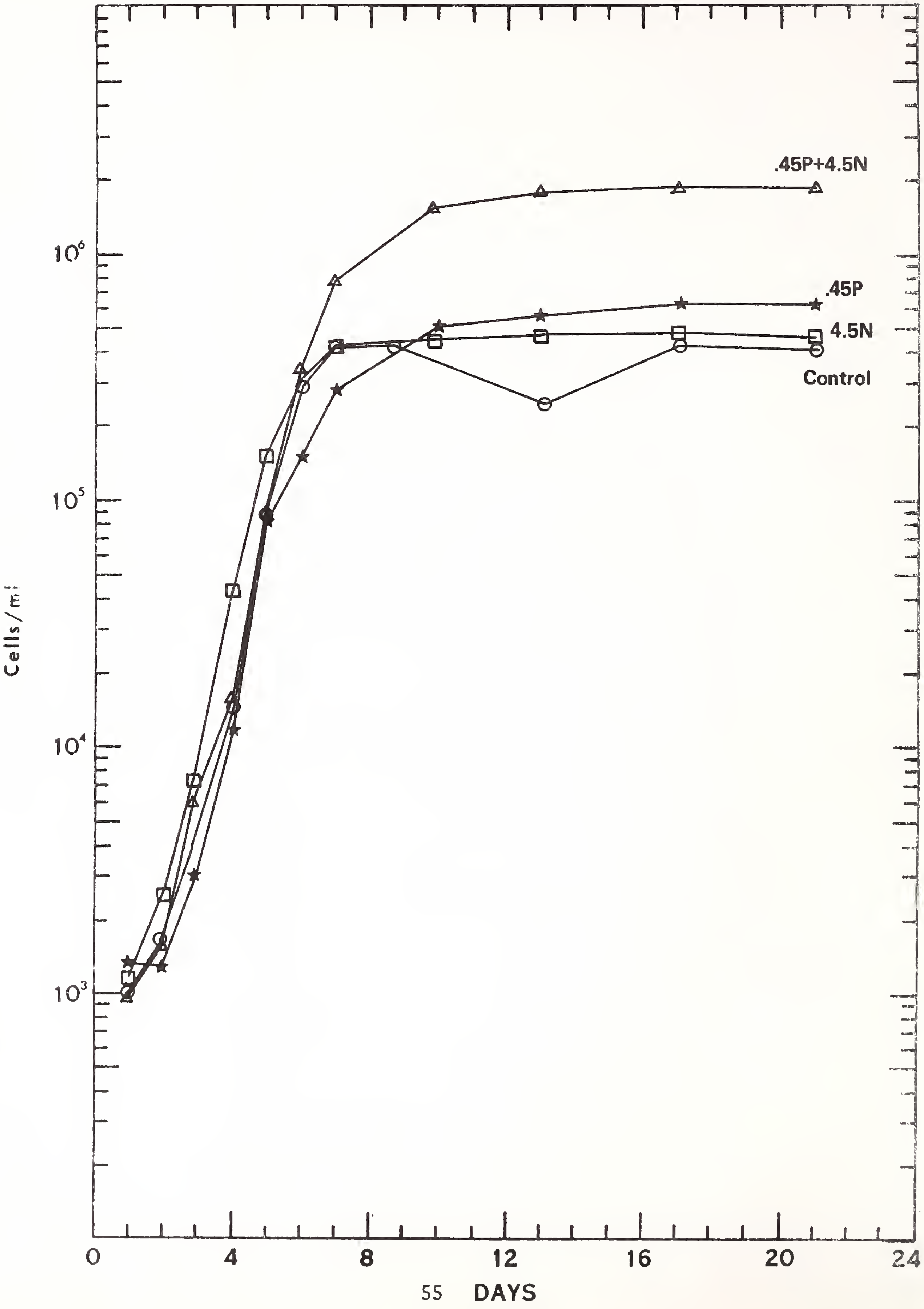


FIGURE 39

Effect of various nutrient additions to water from Station Y on growth of *Selenastrum capricornutum.*

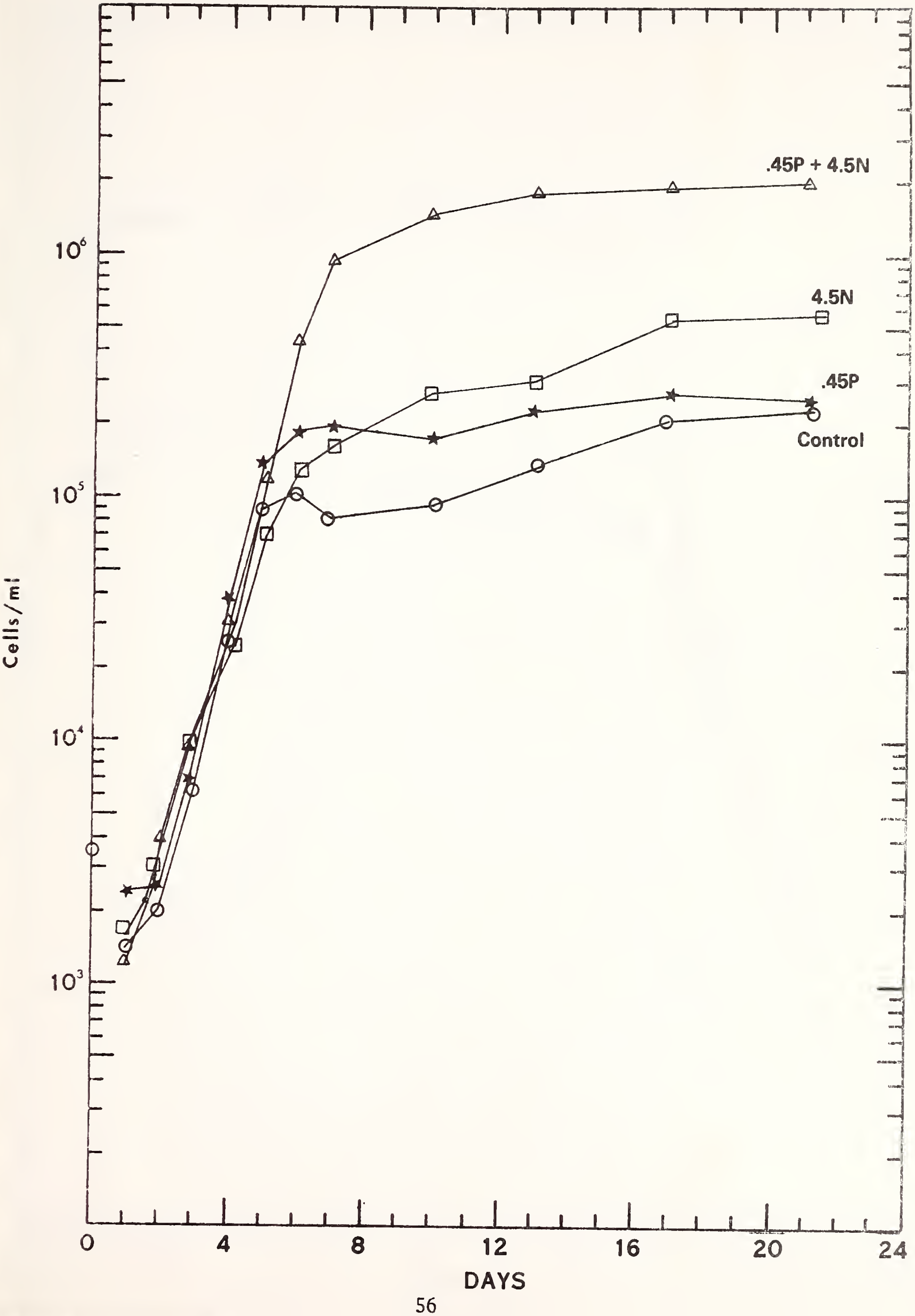


FIGURE 40

Effect of various nutrient additions to water from Station Z on growth of *Selenastrum capricornutum.*

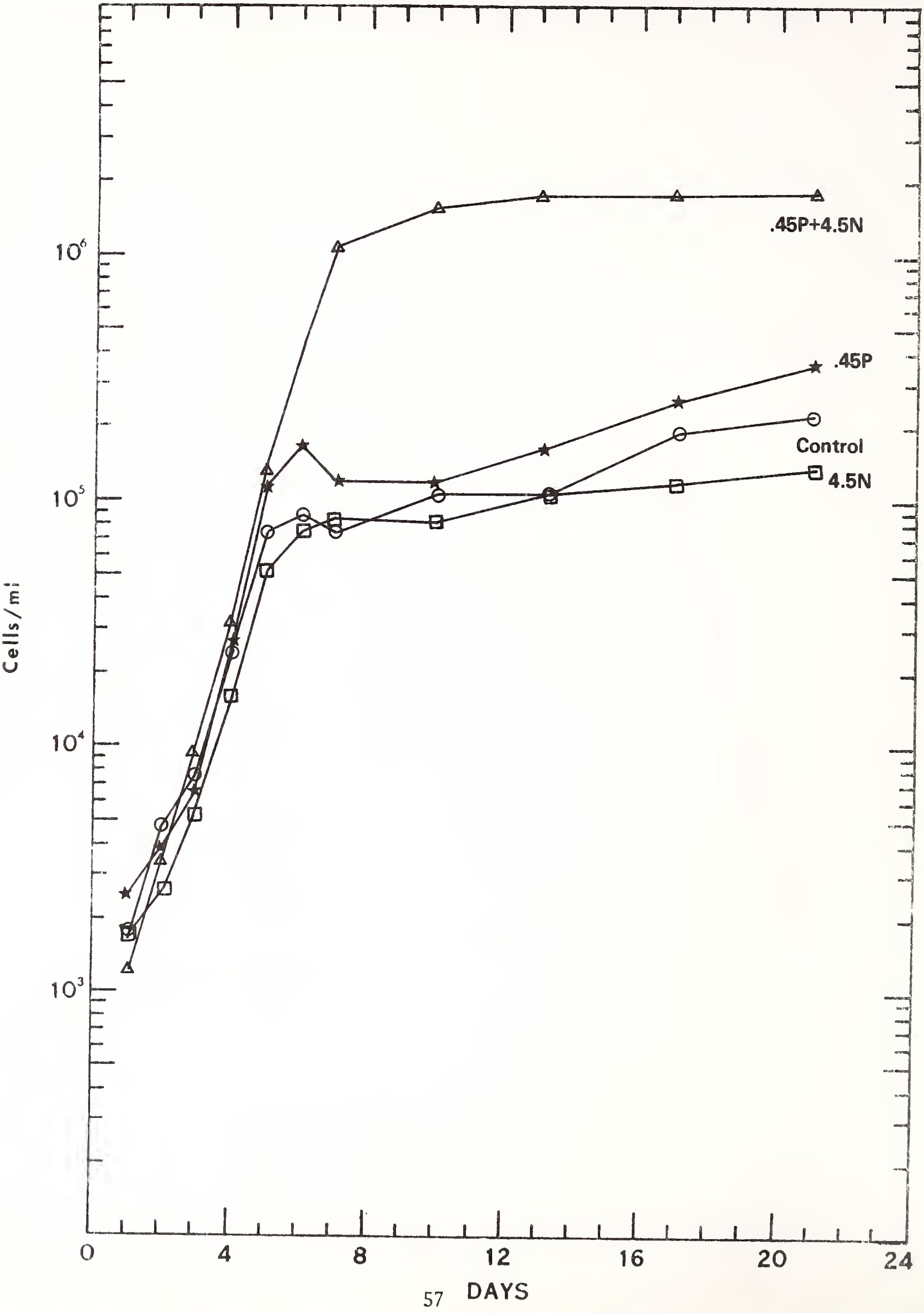


FIGURE 41

Effect of various nutrient additions to water from Station L on growth of *Selenastrum capricornutum.*

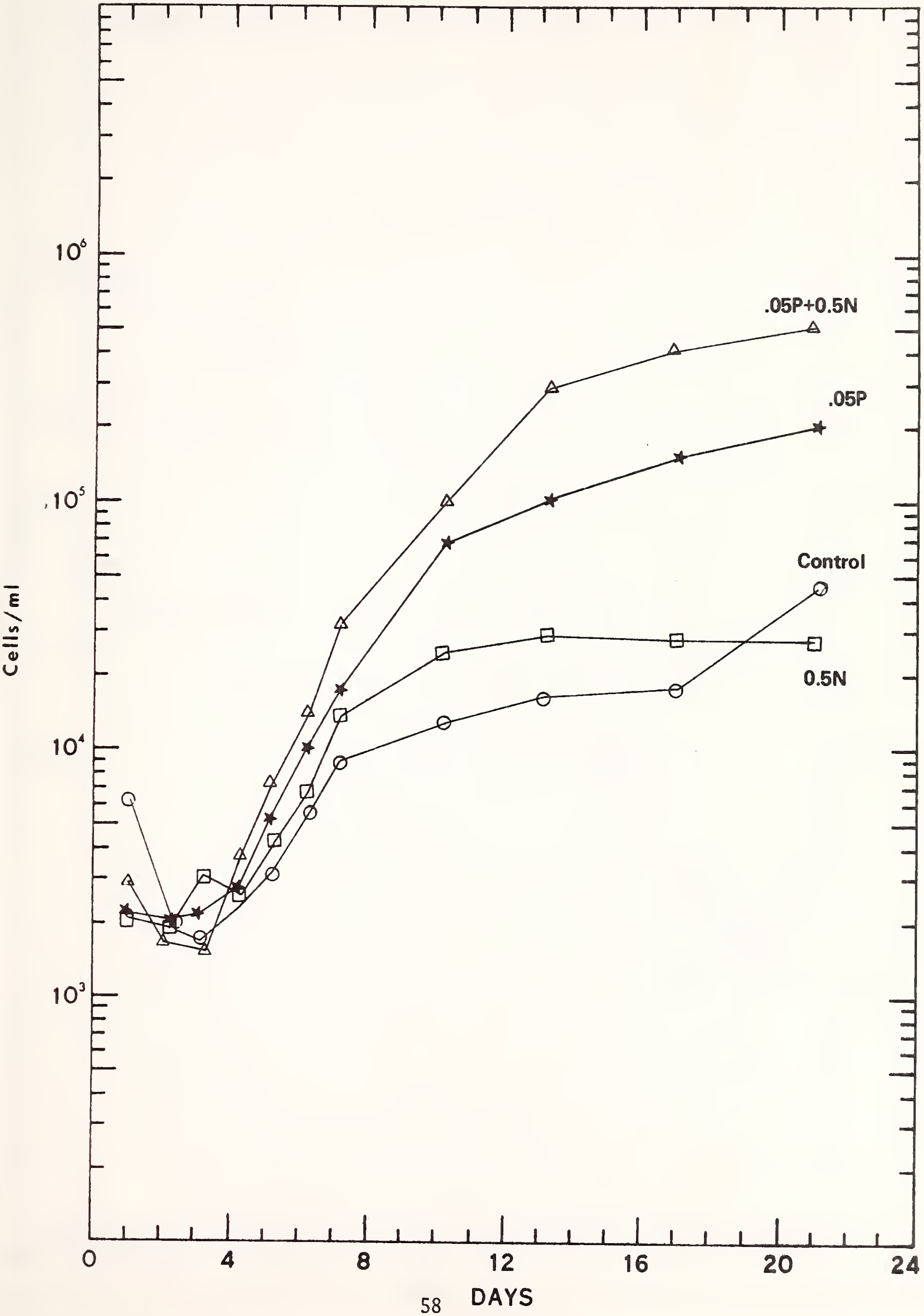


FIGURE 42

Effect of various nutrient additions to water from Station L on growth of *Selenastrum capricornutum.*

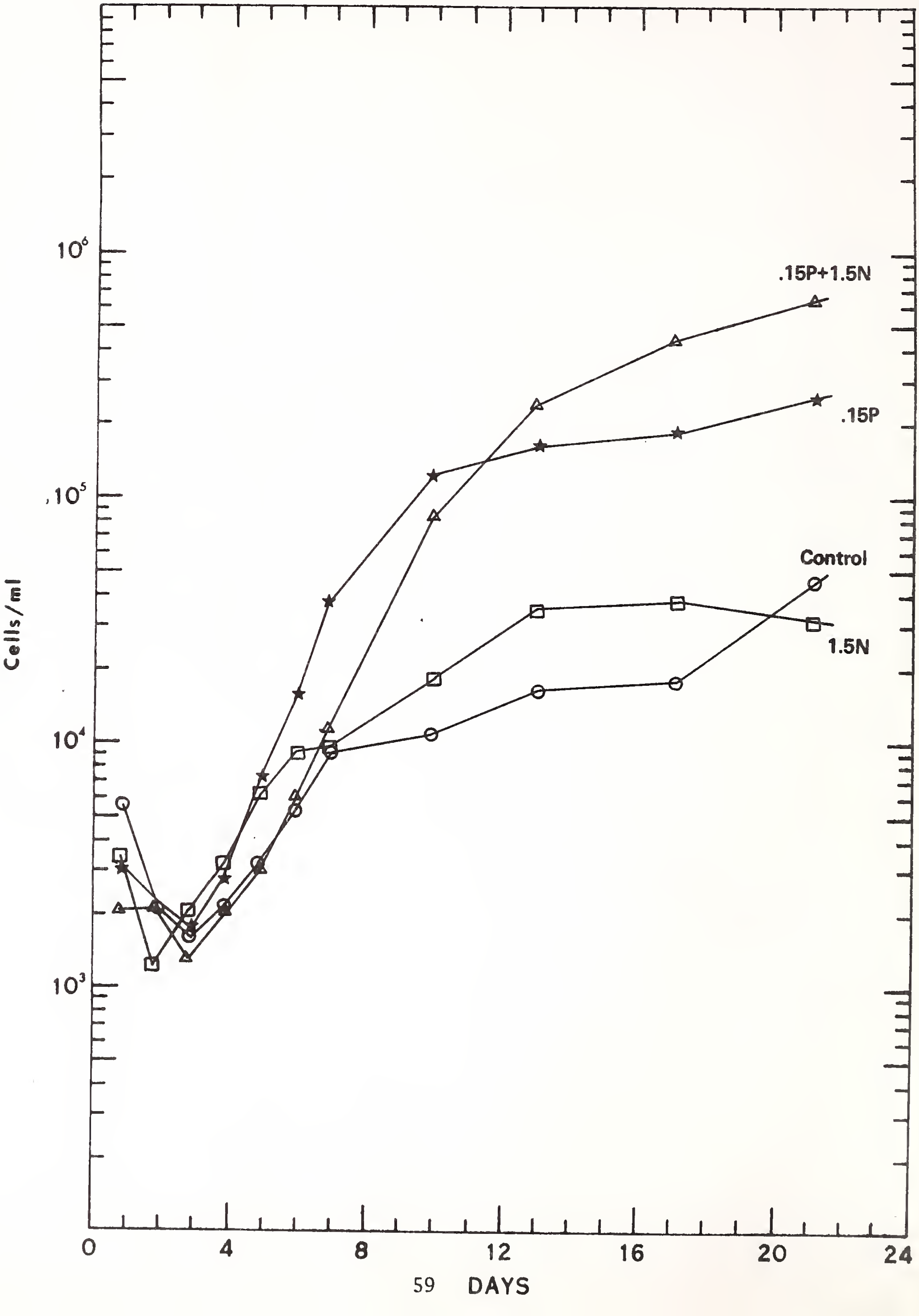


FIGURE 43

Effect of various nutrient additions to water from Station L on growth of *Selenastrum capricornutum.*

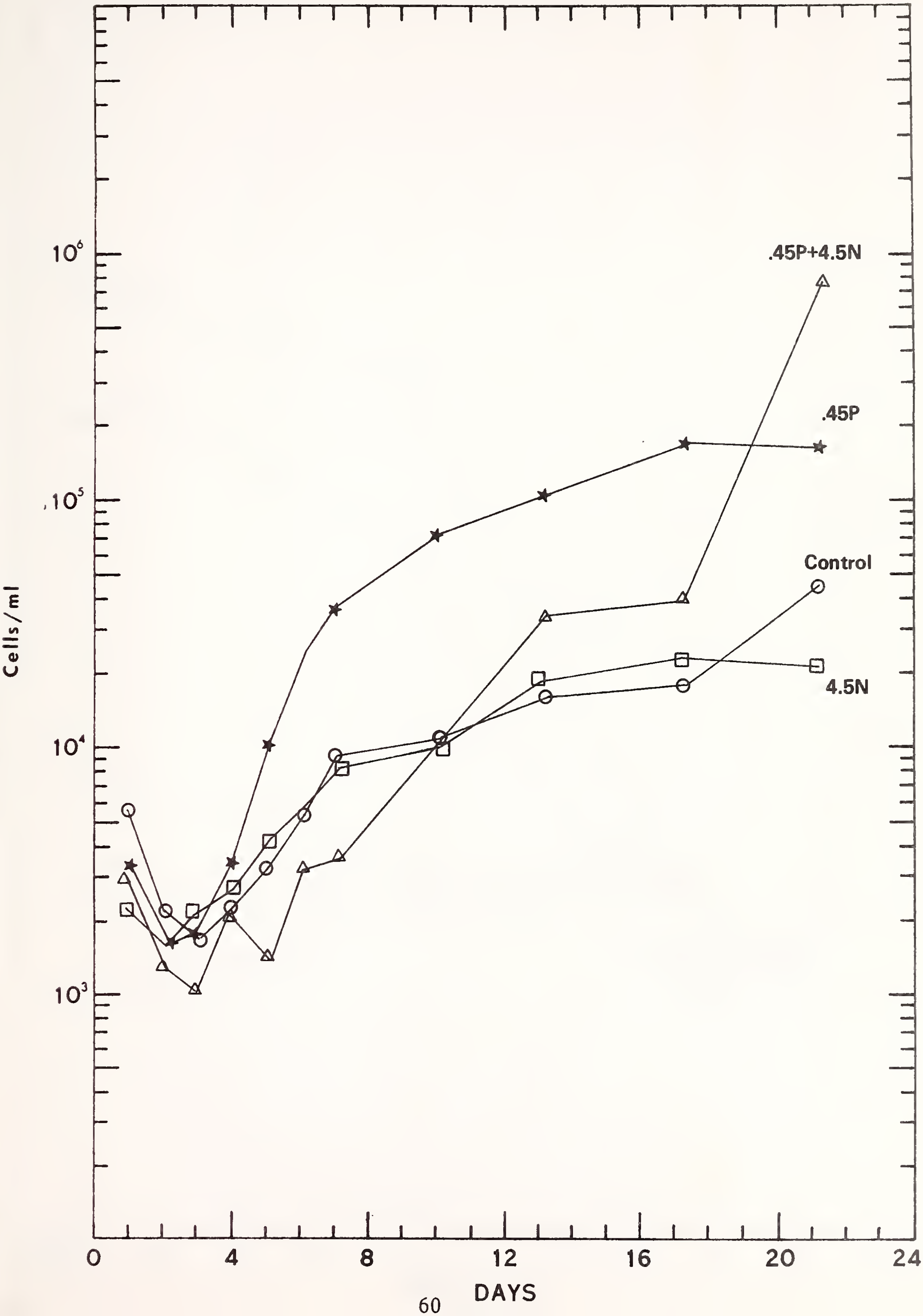


FIGURE 44

Effect of various nutrient additions to water from Station M on growth of *Selenastrum capricornutum.*

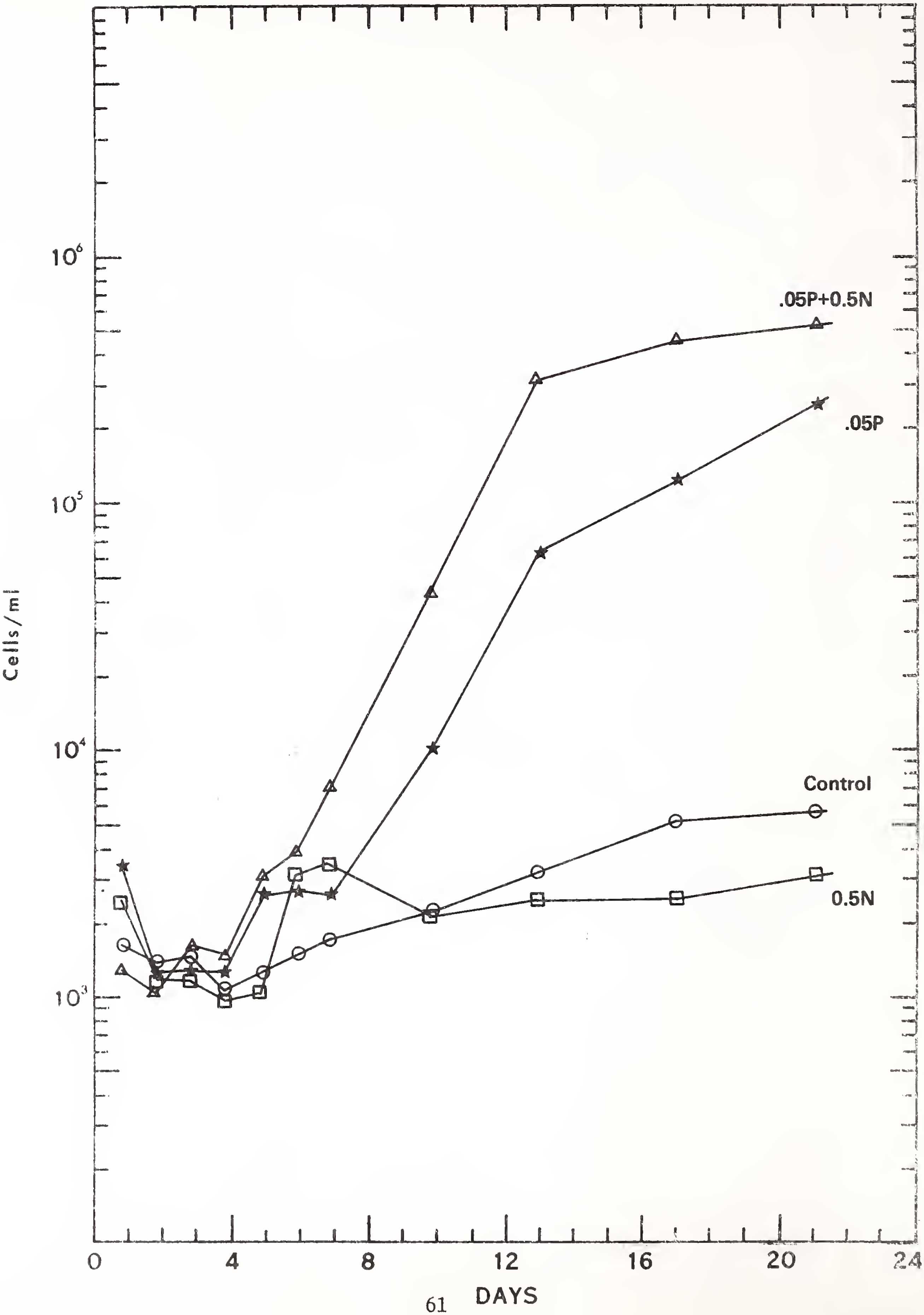


FIGURE 45

Effect of various nutrient additions to water from Station M on growth of *Selenastrum capricornutum.*

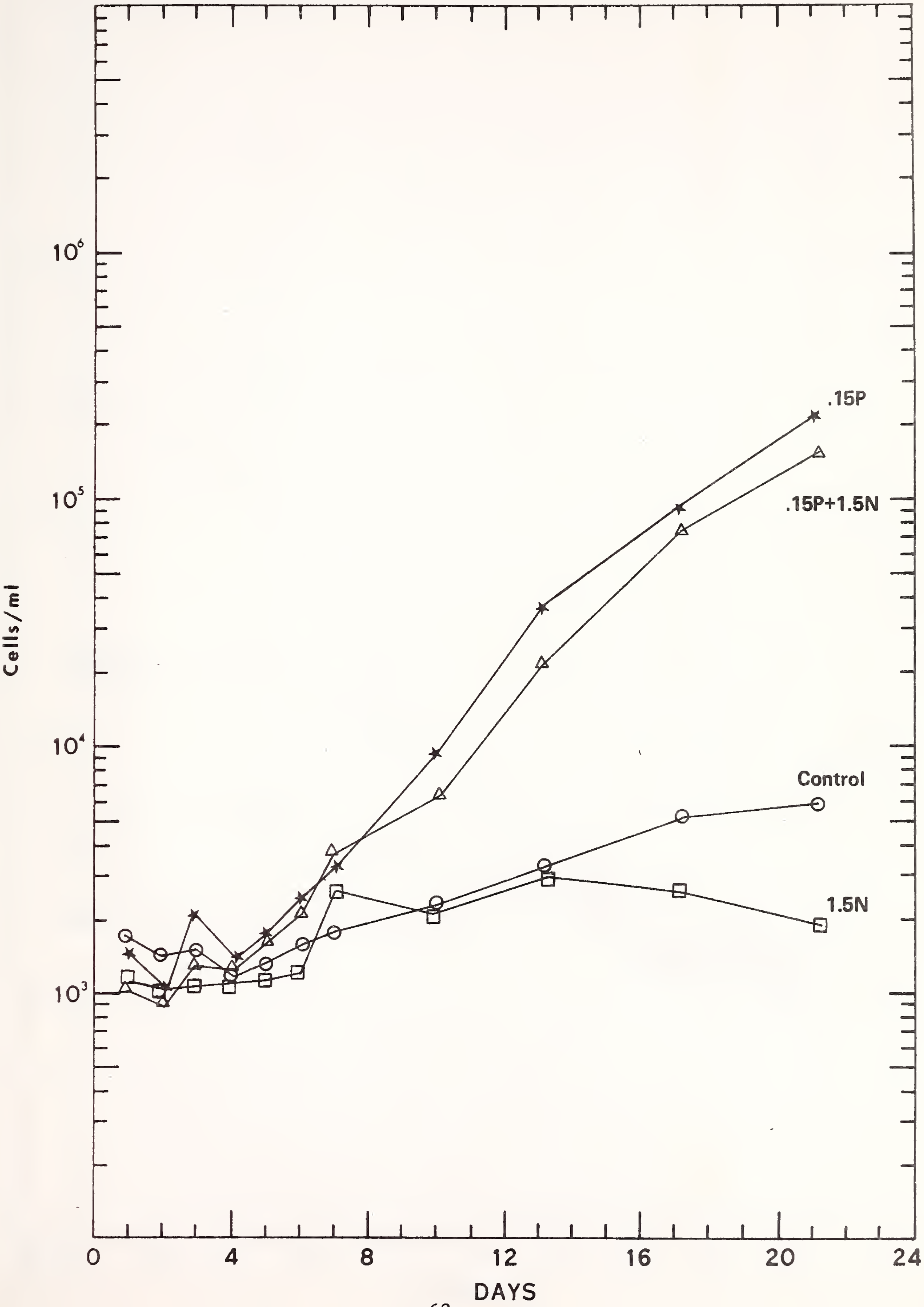


FIGURE 46

Effect of various nutrient additions to water from Station M on growth of *Selenastrum capricornutum*.

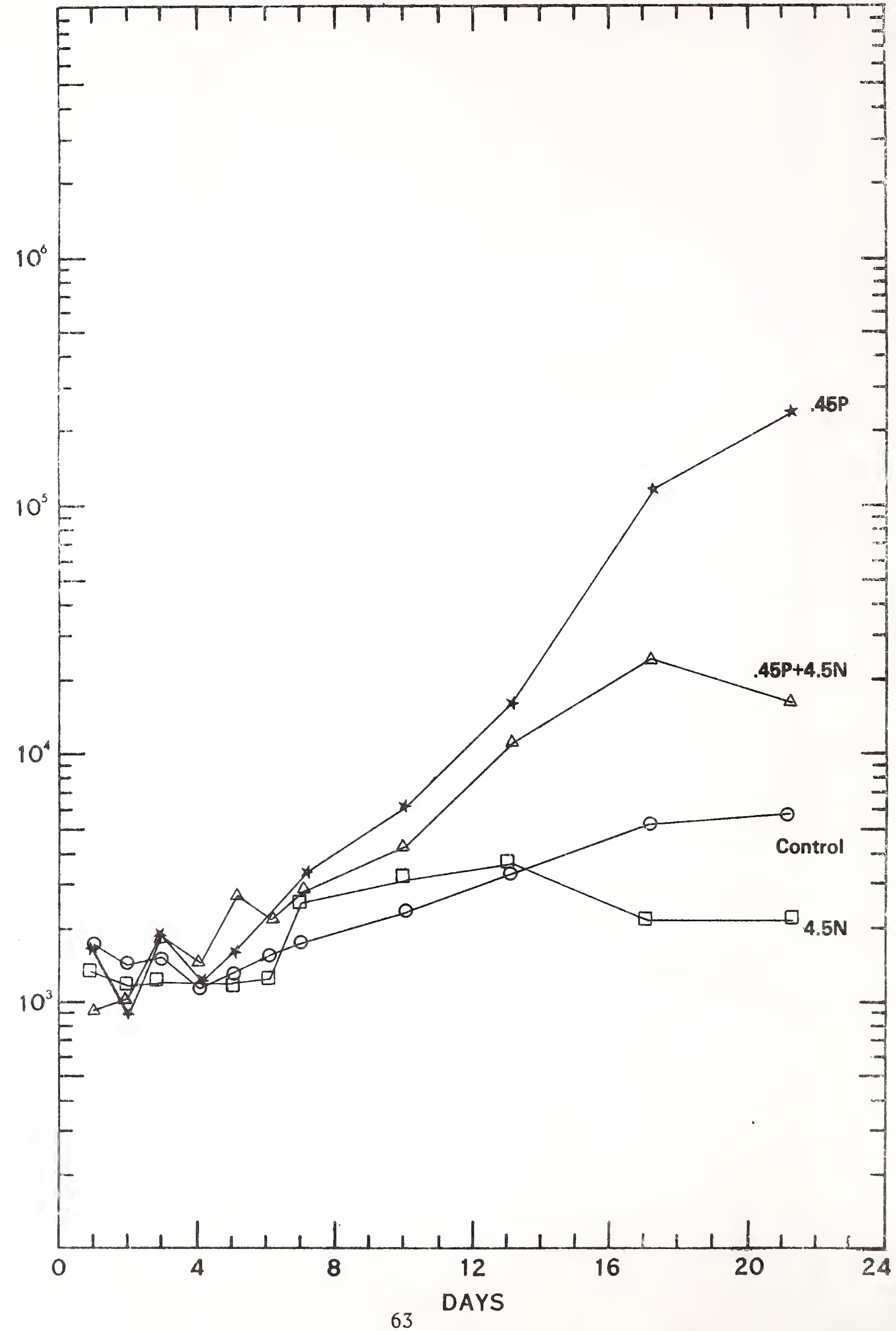


FIGURE 47

Effect of various nutrient additions to water from Station Q on growth of *Selenastrum capricornutum.*

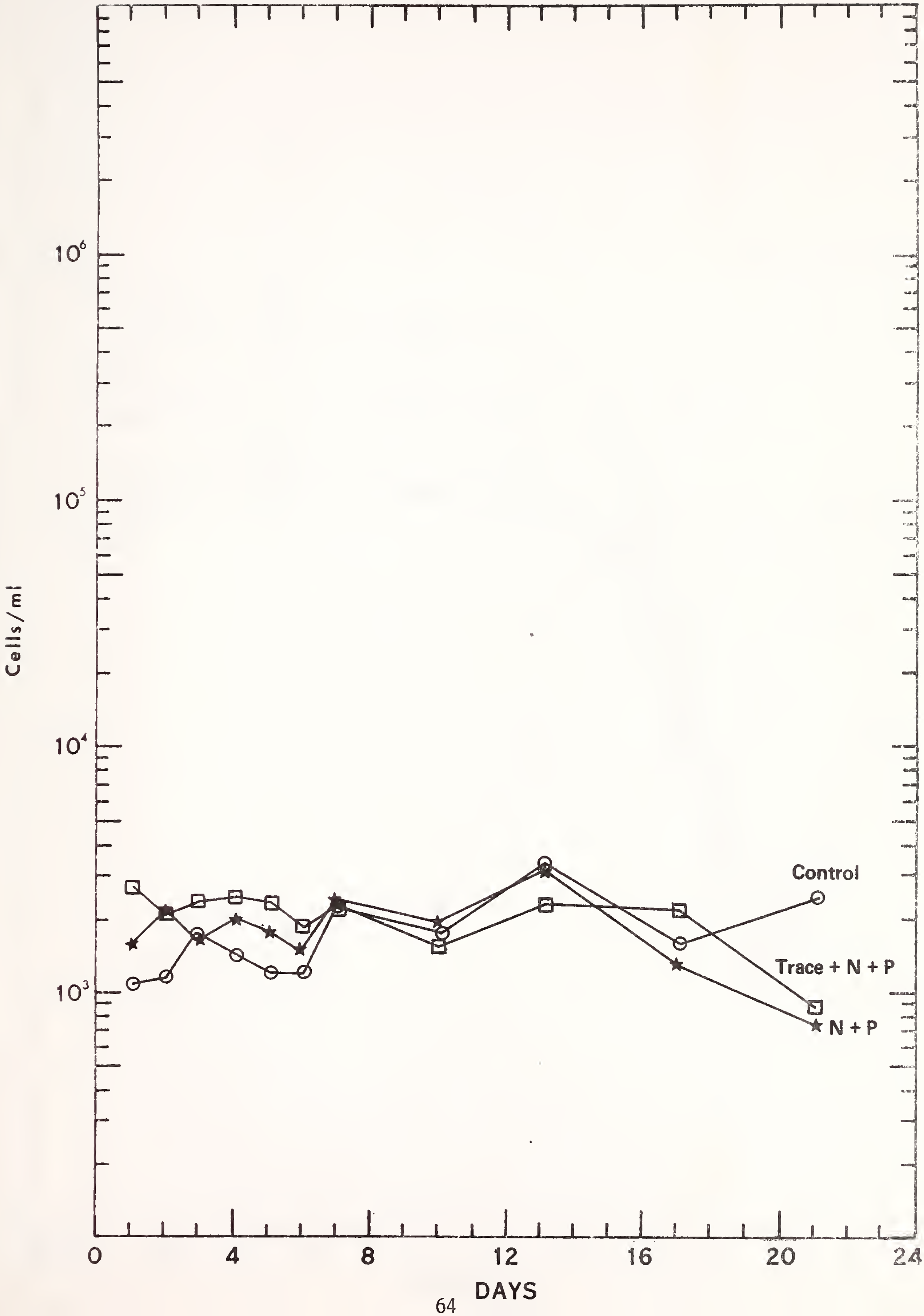


FIGURE 48

Effect of various nutrient additions to water from Station N on growth of *Selenastrum capricornutum.*

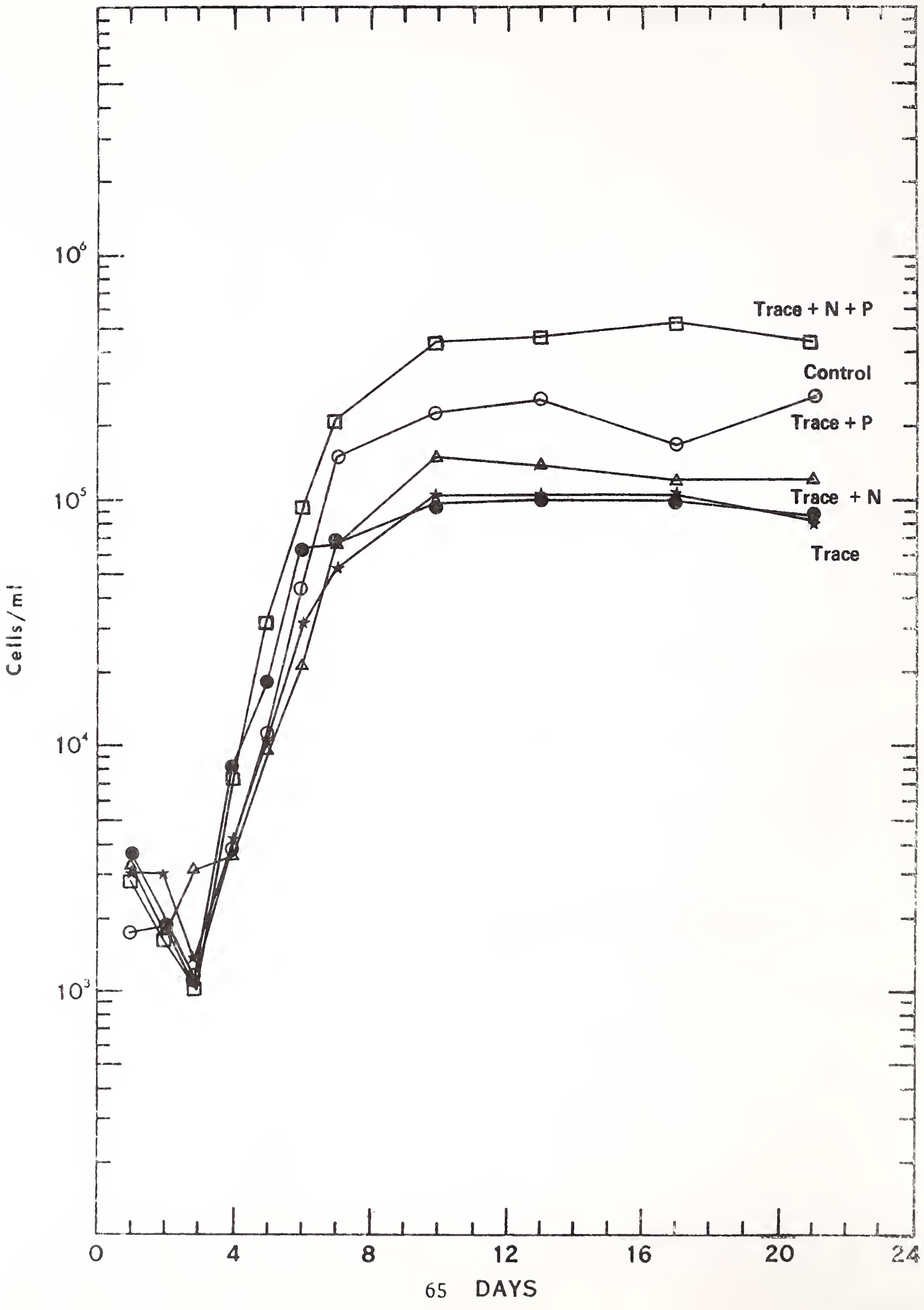


FIGURE 49

Effect of various nutrient additions to water from Station S on growth of *Selenastrum capricornutum.*

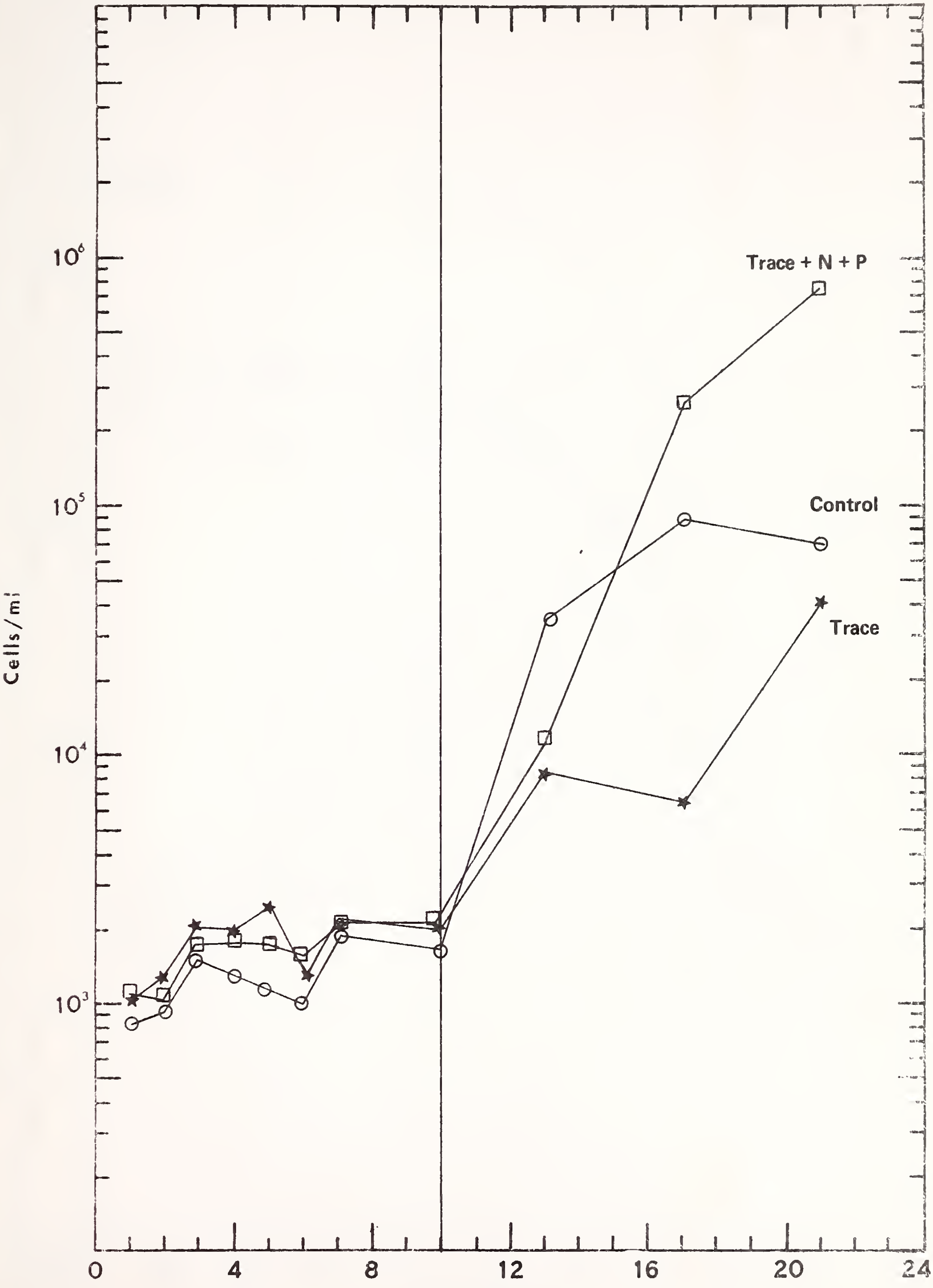


FIGURE 50

Effect of various nutrient additions to water from Station IB on growth of *Selenastrum capricornutum.*

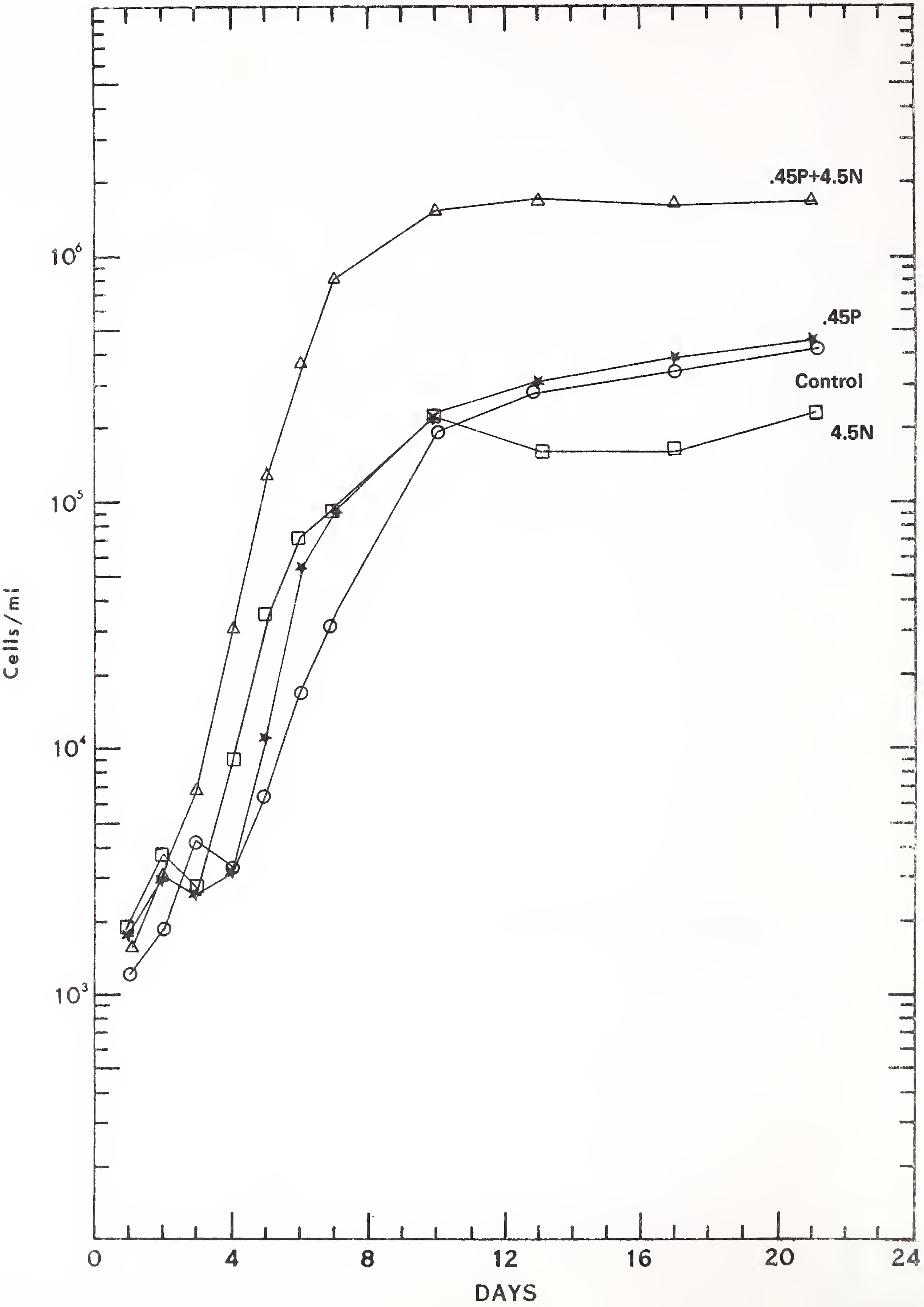


FIGURE 51

Effect of various nutrient additions to water from Station II on growth of *Selenastrum capricornutum*.

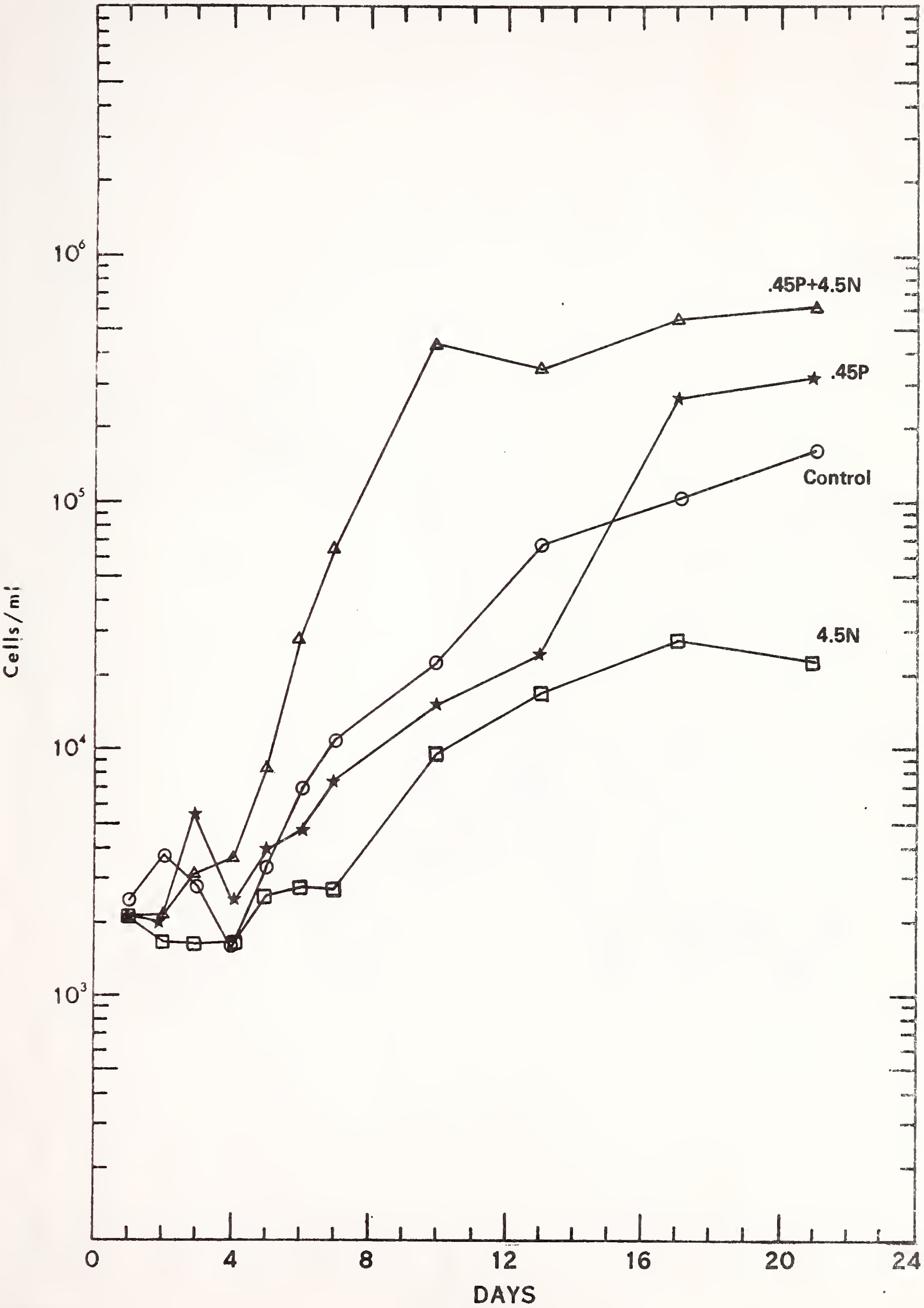


FIGURE 52

Effect of various nutrient additions to water from Station III on growth of *Selenastrum capricornutum.*

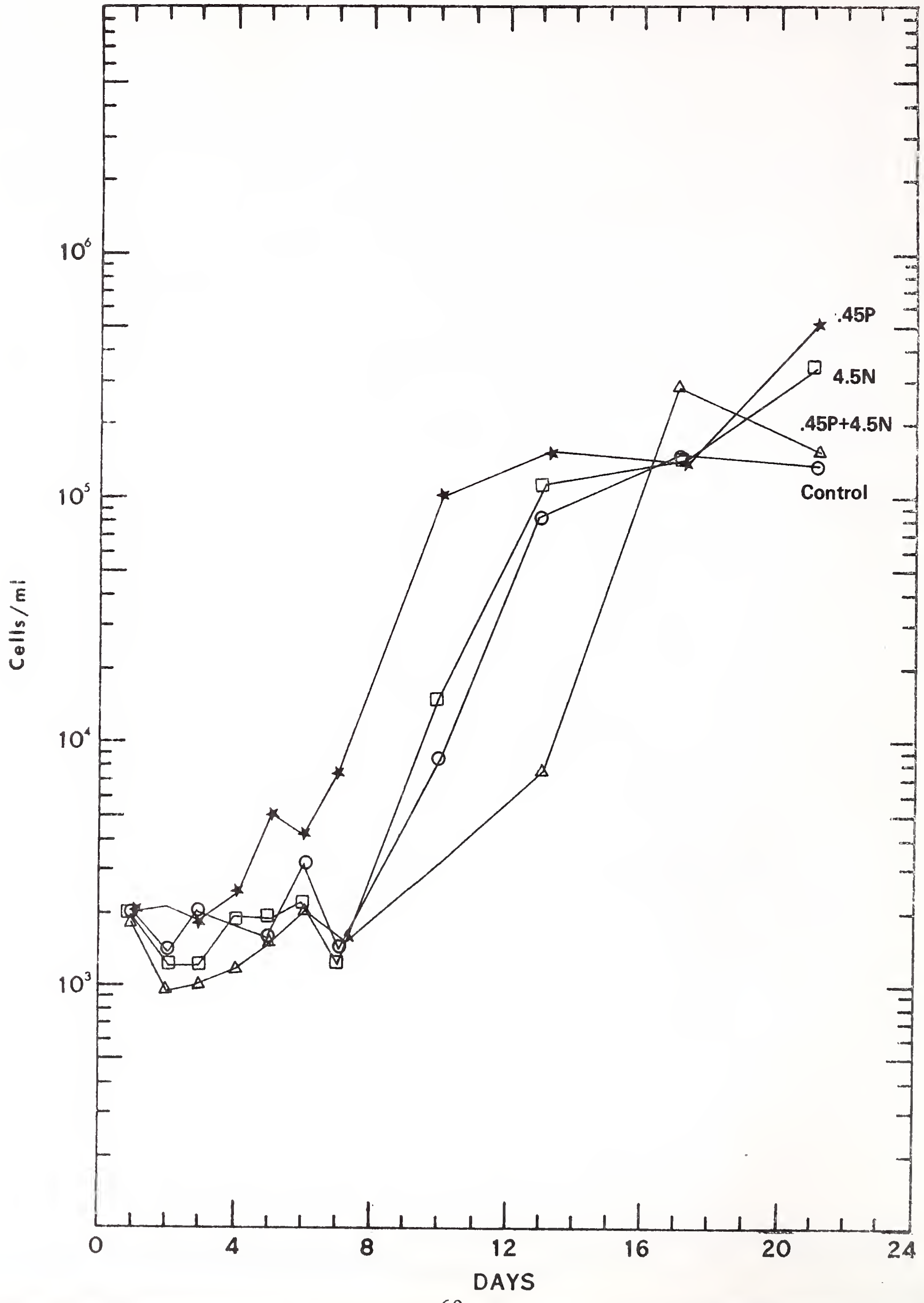


FIGURE 53

Effect of various nutrient additions to water from Station IV on growth of *Selenastrum capricornutum.*

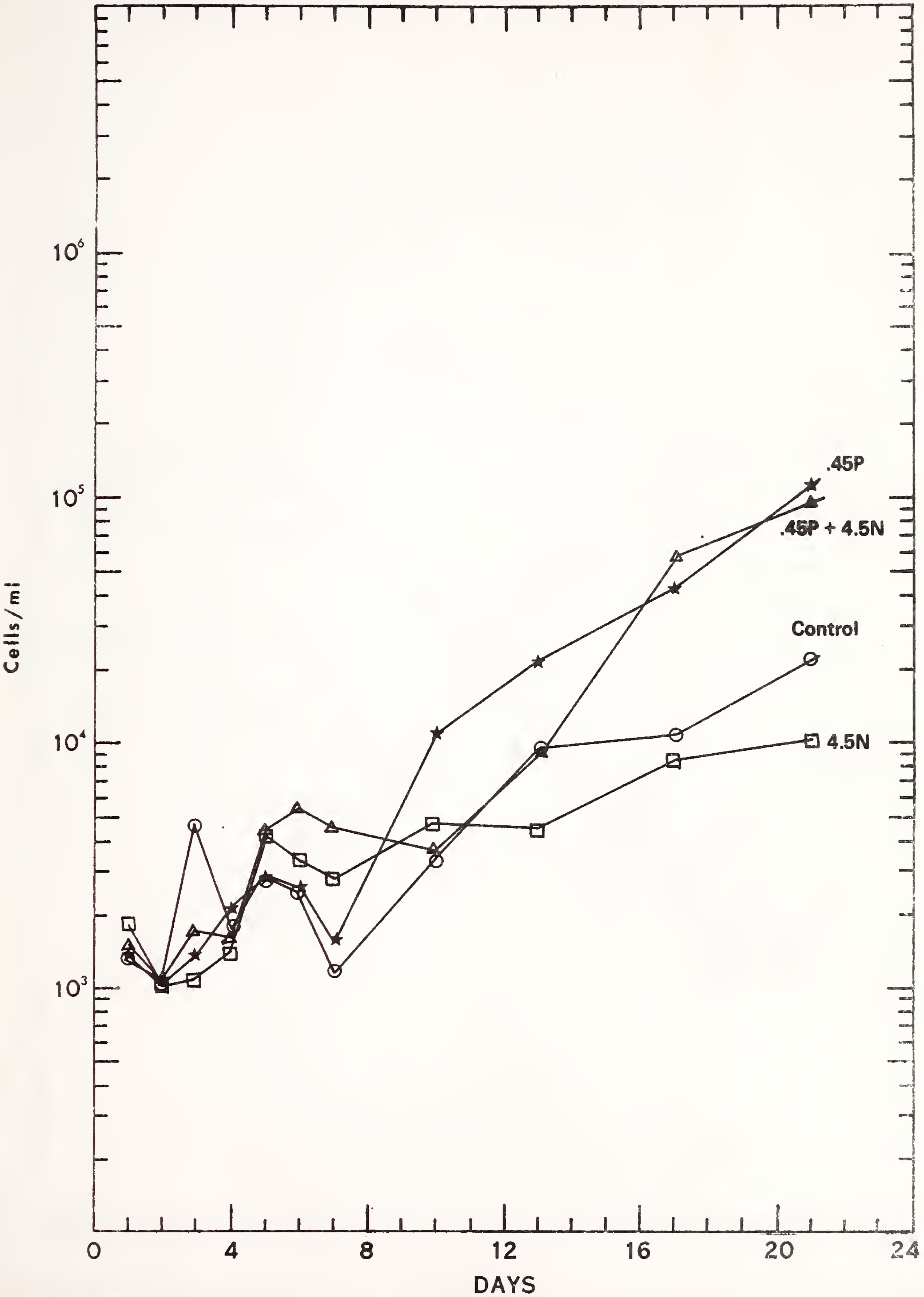


FIGURE 54

Effect of various nutrient additions to ph adjusted water from Station M on growth of *Selenastrum capricornutum.*

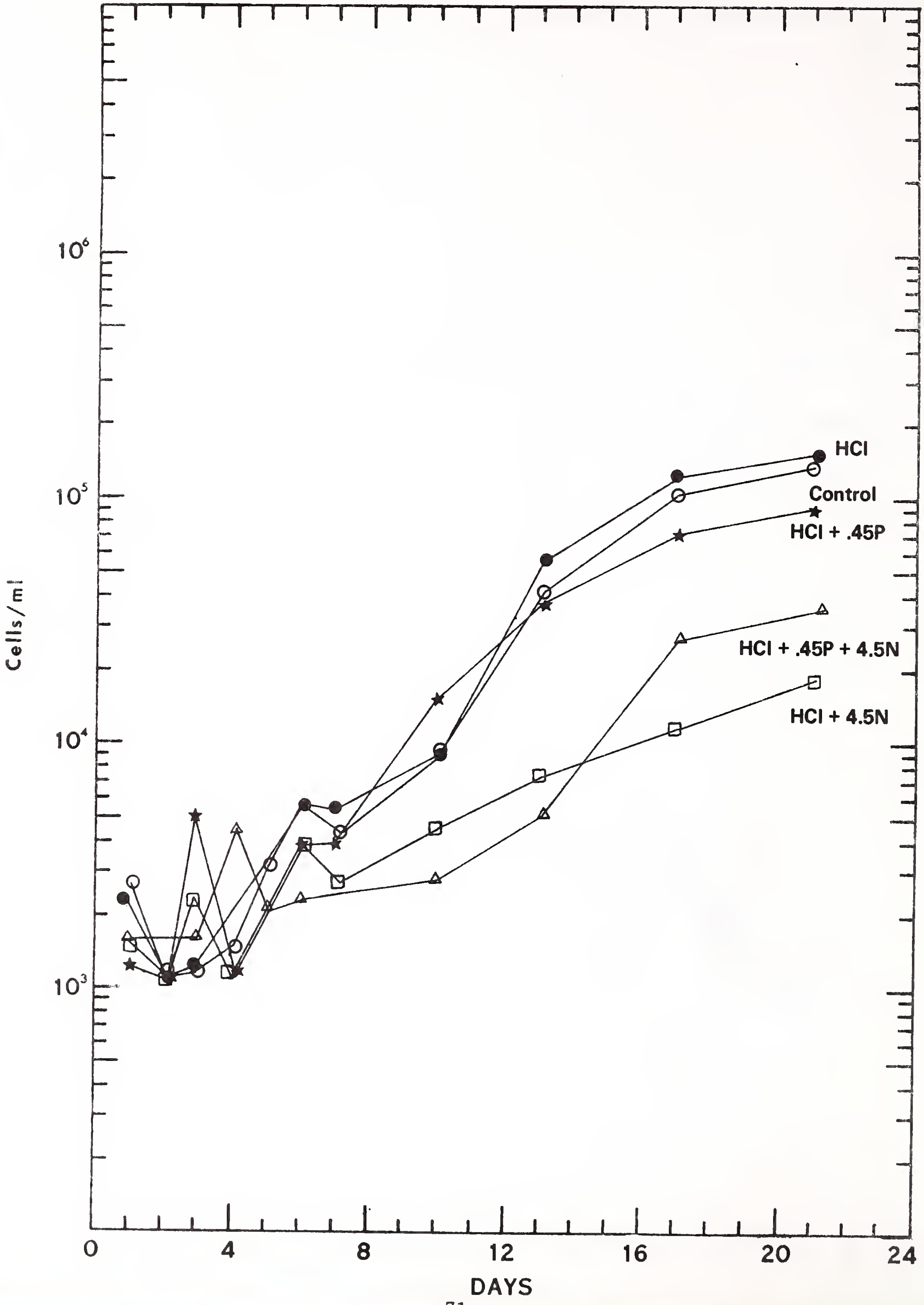


FIGURE 55

Effect of various nutrient additions to pH adjusted water from Station M on growth of *Selenastrum capricornutum.*

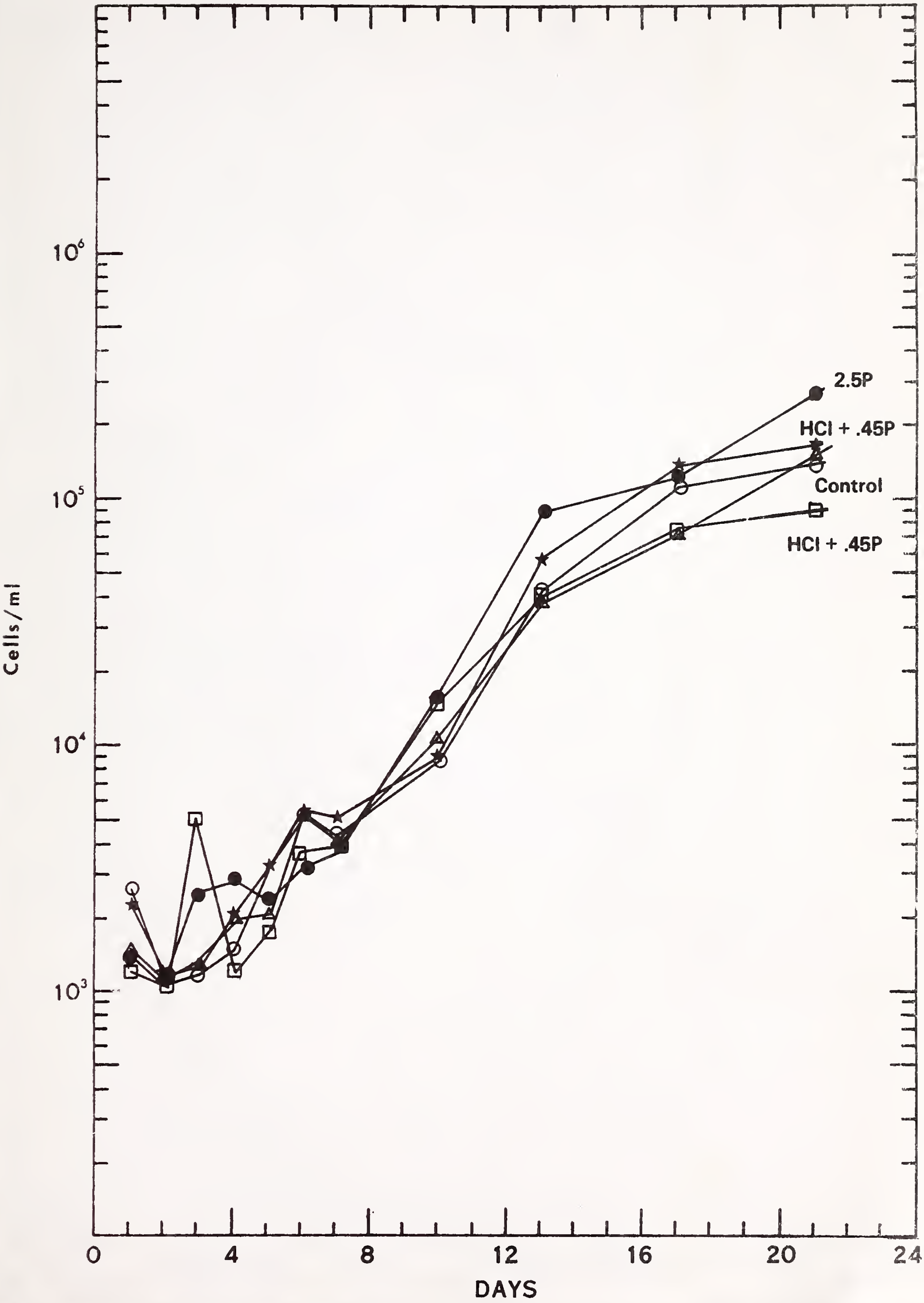
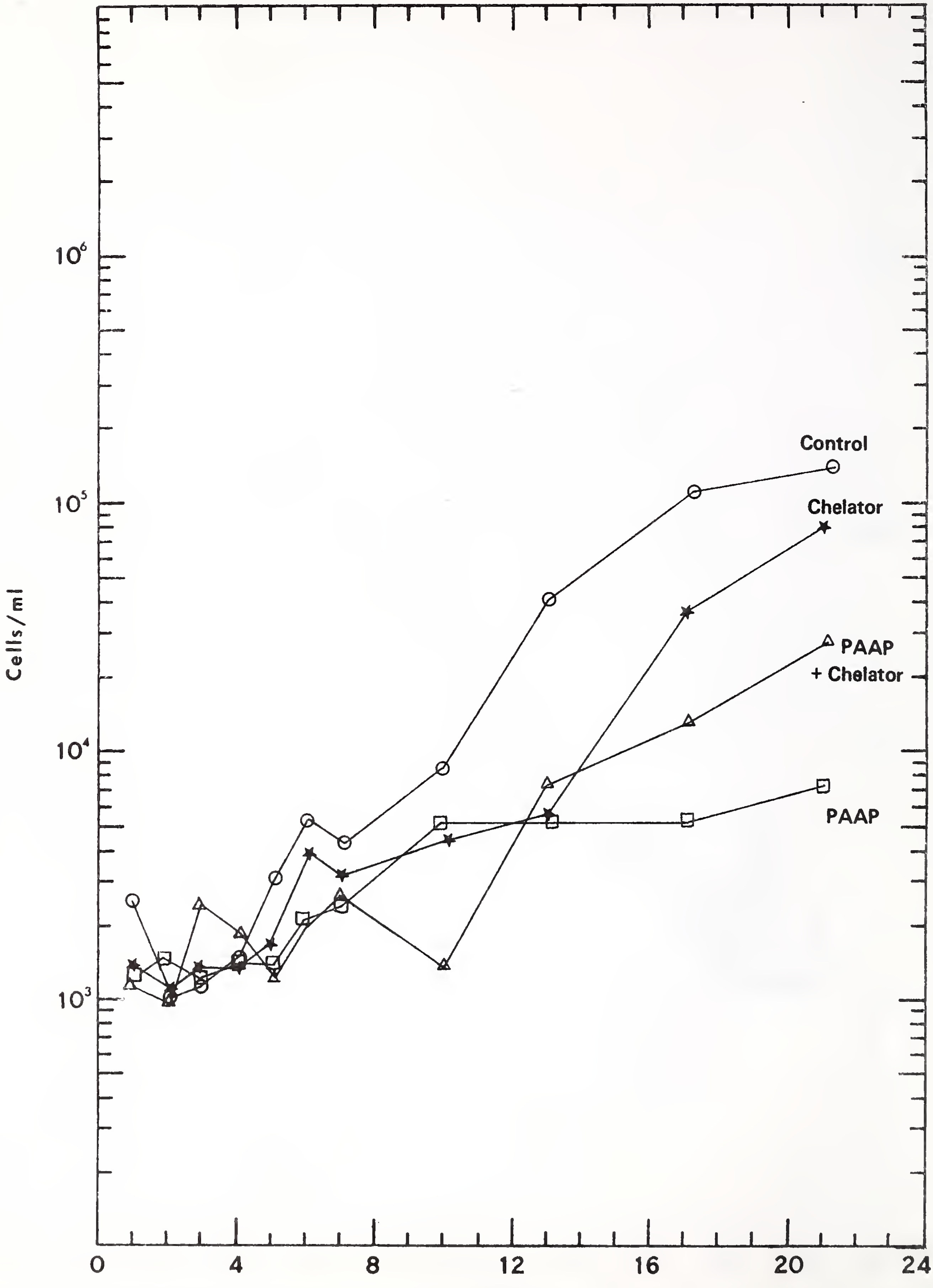


FIGURE 56

Effect of chelator and PAAP media additions to water from Station M on growth of *Selenastrum capricornutum*.



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